DTIC FILE COPY

(4)

AD-A201 296

David Taylor Research Center

Bethesda, Maryland 20084-5000

DTRC/SHD-1190-03 May 1988

Ship Hydromechanics Department

NEARSHORE WAVE CLIMATOLOGY AT KINGS BAY, GEORGIA
AND CAPE CANAVERAL, FLORIDA

by

Ronald J. Lai

Wah T. Lee

Andrew L. Silver

DTRC/SHD-1190-03 Nearshore Wave Climatology at Kings Bay, Georgia and Cape Canaveral, Florida

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED.

88 1027 027

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

AD A201296

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S) DTRC/SHD-1190-03	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION David Taylor Research Center 6b OFFICE SYMBOL (If applicable) Code 1561	7a NAME OF MONITORING ORGANIZATION
6c ADDRESS (City, State, and ZIP Code) Bethesda, MD 20084-5000	7b ADDRESS (City, State, and ZIP Code)
8a NAME OF FUNDING/SPONSORING ORGANIZATION Naval Sea System Command 8b OFFICE SYMBOL (If applicable) Code PMS 396	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (City, State, and ZIP Code) Washington, DC 20362-5101	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO: 11228N PROJECT NO: TASK NO: WORK UNIT ACCESSION NO: DN178318, DN378222

11 TITLE (Include Security Classification)

NEARSHORE WAVE CLIMATOLOGY AT KINGS BAY, GEORGIA AND CAPE CANAVERAL, FLORIDA

12 PERSONAL AUTHOR(S)

Lai, Ronald J., Lee, Wah T., and Silver, Andrew L.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Final	FROM TO	1988 May	

16 SUPPLEMENTARY NOTATION

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

This report is a source document for specifying wind and wave conditions for the Kings Bay, Georgia and Cape Canaveral, Florida areas. The deep water data are derived from the Navy's Spectral Ocean Wave Model (SOWM) hindcast and wave climatology. A Shallow Water Wave Model (SWWM) based on local topography and other physical parameters has been developed to create a shallow water wave climate for ship performance assessments. Several shallow water wave measuring systems, deployed and maintained by the University of Florida, are providing full-scale field data for comparison with SWWM data.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a NAME OF RESPONSIBLE INDIVIDUAL Ronald J. Lai	22b TELEPHONE (Include Area Code) (202) 227-1192 22c OFFICE SYMBOL Code 1561

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

AD-A201296

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S) DTRC/SHD-1190-03	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION David Taylor Research Center 6b OFFICE SYMBOL (If applicable) Code 1561	7a NAME OF MONITORING ORGANIZATION
6c ADDRESS (City, State, and ZIP Code) Bethesda, MD 20084-5000	7b ADDRESS (City, State, and ZIP Code)
8a NAME OF FUNDING/SPONSORING ORGANIZATION Naval Sea System Command 8b OFFICE SYMBOL (If applicable) Code PMS 396	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (City, State, and ZIP Code) Washington, DC 20362-5101	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO: 11228N PROJECT NO: TASK NO: WORK UNIT ACCESSION NO: DN378318, DN378222

11 TITLE (Include Security Classification)

NEARSHORE WAVE CLIMATOLOGY AT KINGS BAY, GEORGIA AND CAPE CANAVERAL, FLORIDA

12 PERSONAL AUTHOR(S)

Lai, Ronald J., Lee, Wah T., and Silver, Andrew L.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Final	FROM ____ TO ____	1988 May	

16 SUPPLEMENTARY NOTATION

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

This report is a source document for specifying wind and wave conditions for the Kings Bay, Georgia and Cape Canaveral, Florida areas. The deep water data are derived from the Navy's Spectral Ocean Wave Model (SOWM) hindcast and wave climatology. A Shallow Water Wave Model (SWWM) based on local topography and other physical parameters has been developed to create a shallow water wave climate for ship performance assessments. Several shallow water wave measuring systems, deployed and maintained by the University of Florida, are providing full-scale field data for comparison with SWWM data.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a NAME OF RESPONSIBLE INDIVIDUAL Ronald J. Lai	22b TELEPHONE (Include Area Code) (202) 227-1192 22c OFFICE SYMBOL Code 1561

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

CONTENTS

CONTENTS (Continued)

FIGURES

FIGURES (Continued)

FIGURES (Continued)

ABSTRACT

This report is a source document for specifying wind and wave conditions for the Kings Bay, Georgia and Cape Canaveral, Florida areas. The deep water data are derived from the U.S. Navy's Spectral Ocean Wave Model (SOWM) hindcast and wave climatology. A Shallow Water Wave Model (SWWM) based on local topography and other physical parameters has been developed to create a shallow water wave climate for ship performance assessments. Several shallow water wave measuring systems, deployed and maintained by the University of Florida, are providing full-scale field data for comparison with SWWM data.

ADMINISTRATIVE INFORMATION

This report was prepared under the sponsorship of the Naval Sea Systems Command (NAVSEA), PMS 396 under Program Element 11228N and Office of Naval Research funding. It is identified by DN Numbers DN178318 and DN378222 at the David Taylor Research Center (DTRC).

INTRODUCTION

Traditionally, shallow water wind and wave environment has played a very minor role in the design and evaluation of marine vehicles. This is largely due to the nonlinear dynamic interaction in nearshore areas which makes wave modeling a difficult task at best. Several shallow wave models have been developed and used in coastal and ocean engineering but the results are far from conclusive. On the other hand, the effort to develop reliable open ocean wind and wave statistics was greatly advanced with the introduction of the Spectral Ocean Wave Model (SOWM) in 1975. Briefly, archived wind data are used by Fleet Numerical Oceanography Center (FNOC) to hindcast the resulting wave fields for approximately 1500 locations (grid points) throughout the Northern Hemisphere.[1] The wind fields are updated at 6 hour intervals over a period of up to 17 years. Thus, the resulting wave directional spectra are really a hindcast time history of wave conditions throughout the

Northern Hemisphere over a period of years. However, the applications of these wave statistics are limited to deep water considerations. Extension of this model to shallow water is needed since there has been an increasing Navy concern about safe ship operations in shallow water areas. The existence of a complex and varied bottom topography along coastal zones, which strongly modifies the wave characteristics, hampers a simple extension of the model to shallow water.

A new approach in developing wave statistics in finite water depth has been carried out at DTRC. This report presents the approach and some results for a region near Cape Canaveral, Florida and Kings Bay, Georgia.

SHALLOW WATER WAVE STATISTICS

APPROACH

The development of wave statistics in finite water depth required two steps. Firstly, a Shallow Water Wave Model (SWWM) based on local topography and other physical parameters has been developed as described in Reference 2. Secondly, several wave measuring stations to calibrate this model were installed at the site of interest, see Reference 3. Simultaneous measurements of local waves at the two stations of both regions and forecast waves at offshore, deep water SOWM grid points have been used to develop shallow water wave statistics. Based on wave direction, height, and period from the SOWM, the correlation between deep water forecast waves (SOWM) and shallow water measured waves was developed. From this correlation, the existing fifteen year hindcast data base from SOWM was transformed to shallow water thus establishing shallow water wave statistics.

The process of transforming waves from deep water to shallow water requires three wave parameters derived from SOWM; significant wave height $(\zeta_w)_{1/3}$, primary incident wave direction (θ_0), and incident modal wave period (T_0). Since the distance between deep and shallow water in this case is less than 120 kilometers and the uncertainty of predicting wave frequency by SOWM, the shift of wave period for long waves (with $T_0 \geq 6.7$ sec) during the transformation process has not been considered. Therefore, the shallow water wave periods are assumed to be the same as the forecast ones from SOWM. The other two parameters are interrelated and are treated separately.

The correlations of significant wave height between deep (hindcast/forecast) and shallow water (measured) were developed using the given forecast wave direction and normalized by the significant wave height of the SOWM at the deep water grid points. The average of three grid points located along the central Florida east coast are used to provide the hindcast/forecast wave spectra for both Cape Canaveral and Kings Bay. These are grid points 248, 222, and 235 which are located at (31.8° N, 75.1° W); (30.4° N, 77.9° W); and (28.8° N, 75.2° W), respectively, see Figure 1. The averaged spectral values of these grid points provides the overall wave forecast by the SOWM at the offshore region.[4]

The changes of approaching wave direction from deep to shallow water are complex on the Florida east coast due to the existence of the Gulf Stream, see Figure 1. Therefore, the process of transforming the forecast wave direction of SOWM into shallow water has been divided into two steps. The first step was to calculate the change in SOWM wave direction from deep water into intermediate depth by crossing the Gulf Stream. Then, by using SWWM, the waves at the intermediate depth were transformed to the shallow water zone.

METHODOLOGY

Cape Canaveral, Florida

Correlation of Significant Wave Height $(\tilde{\zeta}_\omega)_{1/3}$. Based on the two years measured wave data of nearshore stations at Cape Canaveral, the correlation of significant wave height ratio, r, where $r = ((\tilde{\zeta}_\omega)_{1/3})_s/((\tilde{\zeta}_\omega)_{1/3})_o$, $\{((\tilde{\zeta}_\omega)_{1/3})_s$ is the nearshore measured values, and $((\zeta_w)_{1/3})_o$ is the offshore hindcast values), has been developed and shown in Figure 2. In Figure 2, the dashed line represents the empirical curve. The variations of r are ranged from 0.3 to 0.7 depending on the original incident wave direction, θ_o, from SOWM. Waves from the north and northeast directions experience the most reduction. This is primarily due to the shoaling effect of the local topography as described in Reference 2. The solid line in Figure 2 represents the ratio of significant wave height at the channel entrance to the forecast values from SOWM. These ratios are computed from the SWWM by using the forecast wave direction from SOWM as the input for the model. In general, the wave ratio is larger at the channel entrance (offshore) and smaller closer to shore (nearshore). The notable exception occurs when the waves are coming from the southeast direction. The increase in wave heights at nearshore area as the waves approach from the southeast is mainly due to the local shoaling effect as predicted by SWWM in Reference 2.

Transformation of Wave Direction. A simplified analytical solution and numerical model have been used to transform the offshore wave direction to the nearshore zone. In the southeast coast of the U.S., the Gulf Stream dominates the nearshore wave climatology. The Gulf Stream along the Florida east coast heads northward running almost parallel to the coast line. Here, it was assumed that the Gulf Stream is a uniform current, with a mean velocity of 2.0 m/s. The changes of wave directions are calculated from the following analytical solution[5]

$$\cos\theta_1 = \cos\theta_o/[1 - \frac{U_1-U_o}{C_o}\cos\theta_o]^2 \qquad (1)$$

where θ_o and θ_1 are the primary incident and refracted wave directions before and after crossing the Gulf Stream, respectively. U_o and U_1 are the mean currents of the deep water offshore section and the Gulf Stream, and C_o is the original wave phase velocity. The value of U_o was assumed to be zero in this computation.

The relationship between the parameters defined in Equation (1) are shown in Figure 3. The wave direction after refracted by the Gulf Stream is a function of the incident model wave period (T_0) and incident direction (θ_0). The relationship between θ_0, θ_1, and T_0 with assumed values of U_0 and U_1 are shown in Figure 4. When the waves approach from the southeast with large wave periods, the waves may reflect back to the deep water zone as shown in the upper section of Figure 4, this phenomenon has been discussed in References 4 and 5. Furthermore, all the incident waves from the north and northeast are refracted to the wave direction θ_1 with $\theta_1 > 30°$. This implies that the direction of most waves (except the local wind waves) in the intermediate water zone are refracted and arrive in the nearshore zone range from the northeast, the east, and the southeast directions after crossing the Gulf Stream.

The changes in predicted wave direction θ_3 at the nearshore zone were calculated using the hindcast data and are shown in Figure 5. The changes in wave directions depend on the locations of the site and the wave period (T_0) and the wave direction (θ_1) after crossing the Gulf Stream. Here, the site at the channel entrance was chosen. The wave directions are converged to 90° (from the east) which are normal to the shore. The rate of convergence is dependent on the wave period. The longer waves converged faster than the shorter waves, except when the waves came from the easterly direction. The easterly waves change to the southeast direction.

The overall changes in wave direction from the SOWM deep water data to channel entrance at Cape Canaveral are shown in Figure 6. It is interesting to note that the variations in the wave directions in the finite water depth zone are limited to periods of 10 to 14 seconds, the range of the variation in wave direction is from 50 to 135 degrees. This is caused mainly by the Gulf Stream and the shoaling effects at Cape Canaveral. The verification of these results depends on a further field study which includes the measurement of wave direction and will be discussed later.

Kings Bay, Georgia

Correlation of Significant Wave Height. Based on one year measured field data at wave gage station No. 5 at Kings Bay, a correlation of significant wave heights between measured and SOWM data has been developed and shown in Figure 7. The solid line in the figure represents the wave height empirical correlation at wave gage station No. 5. The ratio of significant wave height ranged from 0.3 to 0.5. The range is smaller compared to Cape Canaveral (see Figure 3), although station No. 5 is located further offshore. There is no clear trend in the curves. In general, the waves from the north, northeast and south directions indicate the largest reduction. Other than these directions, the wave height ratio of 0.5 can be used to represent the reduction.

The dashed and dotted lines in the figure are representing the variations of the significant wave height ratio at the channel entrance and near the jetty computed from the SWWM, respectively. These results are computed from the SWWM by using SOWM's data as the initial input data. As the waves came from the northeast direction, the ratio reduced first and then increased at the nearshore zone near the jetty area. When the waves came from the southeast direction, the significant wave height increased at the channel entrance and then reduced near the jetty area. All of these phenomena have been discussed in Reference 2.

Transformation of Wave Direction. The scheme used in Cape Canaveral to transform the wave directions to the nearshore zone has been applied at the Kings Bay area. Due to the change of flow direction of the Gulf Stream and the bottom bathymetry at the Kings Bay area, the results are different from the Cape. The shoreline turns to the northeast direction near the Kings Bay area, so does the Gulf

Stream. The incident wave directions at the offshore zone are then confined to the 40 to 180 degree range. The changes of wave directions after crossing the Gulf Stream around Kings Bay are shown in Figure 8. The offshore wave directions are limited from 40 to 160 degrees range. The nearshore wave directions range then from 70 to 165 degrees according to Equation (1).

The changes of wave directions after crossing the Gulf Stream have been computed in Reference 2. Utilizing the results developed in Reference 2, Figures 9 and 10 show the wave directions from SOWM data as well as the transformed wave directions at the Kings Bay channel areas. At the channel entrance the wave directions are confined from 60 to 145 degrees range as shown in Figure 9. However, the wave directions at the vicinity of the jetty are from 70 to 140 degrees. The effects of bottom topography near the jetty areas strongly modify the wave directions. All of these changes have also been discussed in Reference 2.

LONG-TERM WAVE STATISTICS

The darkened circles around the open ocean grid points on Figure 1 indicate the SOWM grid points used for transformation to the Cape Canaveral and the Kings Bay areas. The SOWM data distributions are developed for the 15-year period from 1959 to 1974. The parameter sets that are developed are

1. Significant wave height versus modal wave period
2. Significant wave height versus primary wave direction
3. Significant wave height versus wind speed
4. wind speed versus wind direction
5. Persistence of wave height
6. Persistence of wind speed

Both annual and seasonal distributions are provided. The seasons are defined by:

1. Winter - December to February

2. Spring - March to May

3. Summer - June to August

4. Fall - September to November

It is noted that the modal periods developed in this work are reflective of the peak of the entire (density) spectrum. Very often this coincides with the peak of the primary direction.

Appendix A provides the data base of open ocean wind and wave conditions derived from the 15-year hindcast wind and wave climatology. Wind and wave data tables are provided for open ocean areas identified on Figure 1. Appendix B provides the transformed wave data for the Cape Canaveral and Kings Bay areas. The wave gage data which generated short-term statistics and the corresponding transformed wave statistics are presented in Appendices C and D. Appendix E provides a description of the data formats which have been employed.

OFFSHORE AREA

Generally sea direction coincides with wind direction which in winter and fall is predominantly from the northeast and in spring and summer from the southeast. In winter, 25.5 percent of all significant wave heights exceed 2 m, 20.5 percent in fall, 8.5 percent in spring, and only 2.5 percent in summer. Modal wave periods are generally 10 seconds or less, however, periods of 17 seconds or more have been measured in winter and fall. The wave heights in winter have occasionally exceeded 5 m from the northeast direction, and are generally of periods of 11 seconds or longer.

Winds are caused by differences in atmospheric pressure, which are caused by variations of vertical air temperature, between two locations. The occurrence of any high wind speeds at this area indicates the existence of a noticeable pressure gradient and in winter 0.5 percent of all measured winds exceed or equal gale forces of 34 knots. The most likely wave heights to accompany the winter gale force winds are between 3 and 6 m and from the southwest. On the average, 30 percent of all winds exceed 15 knots in winter, 26 percent in fall, 13.5 percent in spring, and only 5 percent in summer.

Throughout the year, the occurrence of gale force winds should not persist more than a day. In general, winds which exceeded 20 knots persisted not more than 2.5 days. On the other hand, significant wave heights which exceed 4 meters should not persist more than 1.5 days throughout the year.

NEARSHORE ZONE

The results of wave statistics at Cape Canaveral and Kings Bay areas are given in Appendix E. Wind data graphs are not presented here due to the lack of nearshore wind measurements to develop the correlation with offshore data. Without this correlation, the rapidly changing boundary conditions and the nonlinear dynamic interaction of wind fields at nearshore areas which make the process of generating the wind statistics in the nearshore zone a difficult task. Persistence data are also not available for these areas because after the transformation to nearshore areas all wave data are out of sequence. The area C1 is located 15 miles offshore with mean low water depth of about 16 meters, and C2 is referred to the area next to the channel with water depth of 11 meters at Cape Canaveral. K1 is located 12 miles offshore and K2 is located near the mid-point of the channel with water depths of 18 and 13 meters, respectively, at Kings Bay.

Waves in the Kings Bay area are generally from the east and southeast. In the Cape Canaveral area, the prevailing waves usually come from the northeast, east, and southeast directions. Throughout the year, significant wave heights rarely exceed 3 meters with 0.5 percent for Cape Canaveral and none at Kings Bay. In winter for both areas at Kings Bay, 2.5 percent of all significant wave heights exceed 1.5 meters, 2 percent in fall, 1 percent in spring, and only 0.3 percent in summer. For C1 at Cape Canaveral, 10 percent of all significant wave heights exceed 1.5 meters, 12 percent in fall, 3.5 percent in spring, and only 1.5 percent in summer. At C2 in winter, 3 percent of all significant wave heights exceed 1.5 meters, 2 percent in fall, 1 percent in spring, and only 0.5 percent in summer. Modal wave periods are generally 10 seconds or less; however, periods of 17 seconds or more have been measured in winter and fall.

In general, the wave heights at Cape Canaveral are more severe than at Kings Bay. This is probably due to the location of Kings Bay at the embayment of the Continental Shelf which causes the Gulf Stream and the storms to turn away from the coastline.

SHORT-TERM WAVE STATISTICS

MEASURED WAVE STATISTICS

Wave data collected from the field are valuable in that they play an important role in the development of local wave climatologies. The field data described in this section were used to calibrate the Shallow Water Wave Model (SWWM) and to establish short-term wave statistics. The procedure and the results have been documented in Reference 3. The biaxial current meter/pressure gage combination has been the primary wave sensor presently used at both Kings Bay and Cape Canaveral (sensor B of Fig. 2 and Stations 4 and 5 of Fig. 3 of Reference 3).

The data recovery rate during the first year for C1 (sensor B) has been around 65 percent. The seasonal wave data presented in this section are fall and winter for area C1. In general, waves with modal wave period of 7 seconds or long occur more than 70 percent of the time. These long waves usually come from the northeast and east. This is consistent with the transformed data in Appendix B.

The data recovery rate during the first year at K1 (Station 5) has been around 60 percent. Wave data for spring, fall, and winter seasons are presented for area K1 at Kings Bay. Waves with modal wave period of 7 seconds or longer occur 60 percent of the time. Periods of 11 seconds or more have been measured during winter and spring. The dominating wave period during the fall season is around 8.6 seconds. Throughout the year, due to the effects of the Gulf Stream, most of the waves usually come from the east. The transformed wave data also show the same trend as the measured data except for the wave heights. On the average, the measured significant wave heights are about 1 meter higher than the long-term transformed significant wave heights.

TRANSFORMED WAVE STATISTICS

Based on the transformation method developed previously, other short-term wave statistics at the nearshore zone were also generated and are listed in Appendix D. These wave statistics are generated from hindcast SOWM's data and correspond to the same period of time as measured data in Appendix C. These statistics were used to calibrate the transformation method developed here. The excellent agreement between these two sets of data provides the verification of the transformation method. Further discussion of the comparison will be given in the following section.

DISCUSSION

COMPARISON WITH MEASURED DATA

Based on the shallow water wave model (SWWM), measured field data, and taking into account the effects of the Gulf Stream, the nearshore climates at Cape Canaveral, Florida and Kings Bay, Georgia have been developed and presented in the previous section. As mentioned in Reference 3, several field measuring stations have been set up to collect the field data. These measured data have been used to test the validity of the method and the accuracy of the statistical results.

Significant Wave Height

The method using SOWM hindcast/forecast wave information with proper transformation has been developed. The results will be compared with field measured data. The comparison of daily variation of significant wave height from SOWM after transformation and field measured data are shown in Figs. 11 and 12. The solid lines in the figure are predicted values using SOWM and the dashed lines are from field measurements. The agreement between these methods are reasonable. Although the measured values showed some fluctuations at the Cape Canaveral area (see Fig. 11), the fluctuations are mainly caused by the energy input from the local wind force which did not include the transformation process. In general, the storm predicted from SOWM eventually showed up in the nearshore zones. The duration of the storm agrees well although actual starting time may not coincide and the maximum strength of the storm may not be the same value. The procedure to extend the offshore forecast waves into the nearshore has been established with agreeable results with field measured data.

Short-term Statistics

The field measuring stations have been operated nearly three years. The data recovery rate at the nearshore zone is about 55 percent.[3] The data recovery rate was good at the early stage of deployment and deteriorated recently due to life span of the instruments and damage by the fishing nets. After carefully screening the measured directional wave data, three sets of short-term wave statistics were developed in Appendix C and compared with corresponding transformed hindcast statistics from SOWM in Appendix D.[6]

The data are basically generated seasonally at two farshore locations, one in Kings Bay and the other in Cape Canaveral. Three sets of statistical data have been generated here for comparison. Here, K1-2 refers to Kings Bay station during winter of 1984, K2-5 refers to Kings Bay station during fall of 1984 and C1-5 refers to Cape Canaveral station during fall of 1985.

Comparison of measured and hindcast wave direction statistics are shown graphically in Figs. 13, 14, and 15. Here the wave directions are confined from 0 degree (north) to 180 degrees (south). The solid lines represent the offshore hindcast data from SOWM. The dashed lines represent the nearshore transformed hindcast data and the dotted lines represent the measured field data at the same period of time. Each figure is divided into parts (a) and (b). The analyzed results of long waves are shown in part (a). Overall agreement for the long waves is evident especially for the waves from the north, northeast, and east directions. Here, the long waves are defined as the waves with periods longer than 6.7 sec (or frequency less than 0.15 Hz). There is only a little improvement on the waves from the south and southeast directions due to the complex phenomenon of wave reflection and less accuracy for predicting waves generated from the south near Little Bahama Basin by the SOWM (see also Fig. 1). The data in part (b) consist of all waves. The results of part (b) show that the transformation method which takes into account the effects of the Gulf Stream and the local shoaling zone are doing a good job. The waves from north, northeast, and east directions refract to east which is normal to the shore as predicted from the ray theory. However, the waves from south and southeast directions reflect to the offshore which is difficult to assess in the transformation process. Furthermore, when offshore waves cross the Gulf Stream, longer waves tend to follow the ray theory and short waves are affected by the currents and local wind force. Local energy inputs interact dynamically with short waves and cause the waves to break or reorganize. These have been clearly indicated from the measured data.

Comparison of measured and hindcast wave period statistics is shown in Fig. 16. The solid lines are from the hindcast data of SOWM and the dashed lines are from the field measured data. The wave periods from SOWM between offshore and nearshore after crossing the Gulf Stream are the same. The results show the direct comparison of SOWM with measured data. The agreement is encouraging if one separates the long and short waves again. The overall wave period of long waves between two data sets agrees well although the distribution is not very consistent. Further research is needed to take into account the local wind force on wave evolution.

Comparison of measured and hindcast significant wave height statistics is shown in Fig. 17. The agreement between transformed hindcast data from SOWM and field measured data in the Kings Bay area is very good but not in the Cape Canaveral area. The reason for this poor agreement in Cape Canaveral area is not clear. After re-examining the data of Cape Canaveral, it was found that some storm data during the winter of 1985 are from the south and southeast directions which may be attributed to this poor agreement.

COMPARISON WITH OTHER AVAILABLE STATISTICAL RESULTS

Recently, the U.S. Army Engineering Waterway Experiment Station (WES) under the Wave Information Study (WIS), published Atlantic Coast Hindcast.[7] The WES model is divided into three phases with Phase I the offshore zone, Phase II the transitional zone, and Phase III the nearshore zone. Because Phase III development has not been completed, the comparison of results will be concentrated on Phase II. The grid points selected from Phase II are either located in or at the edge of the Gulf

Stream and were chosen because they are located geographically close to the area of this study.

In principle, the equations for wave growth, dissipation, and anglar spreading relative to the wind direction between SOWM and WES models are similar except the variation of parameters used in a time-invariant propagation. The major differences between these two models are the initial conditions, wind forcing and wave propagation algorithms.[8,9] As the waves approach the nearshore zone, the effects of the Continental Shelf and associated currents, local topography and tidal variation are all making contribution to the wave characteristics. The statistical long-term results generated from SOWM and WES are shown in Figs. 18 and 19 for Kings Bay, Georgia and Cape Canaveral, Florida.

In Figs. 18 and 19, the solid lines came from SOWM and the dashed lines are from WES. Each figure consists of three groups, i.e., wave height (a), wave direction (b), and wave period (c). Each group consists of two seasons, i.e., winter and fall at these two locations. As for the results of wave height statistics, the agreement at the Kings Bay area are always better than at the Cape Canaveral area. Hindcast data of significant wave height from WES are generally higher than from the SOWM.

As for wave direction statistics, the direct comparison will bias the results since the two models use different windows to group the statistics. In order to compensate the percentage of occurrence has been normalized by directional window, i.e., 30 degrees for SOWM and 22.5 degrees for WES. The results show some agreement and disagreement. At the Kings Bay area, the maximum prcentage of occurrence is from the east direction. The results for both models agree in this but the values are quite different. At the Cape Canaveral area, the general agreement exists but not consistent.

For the statistical analysis of the wave period, the percentage of occurrence has to be normalized in order to compare. The comparison of these normalized percentage of occurrence are shown in Fig. 18(c). A large percentage of long waves are hindcasted from SOWM while WES data consists of a large portion of short waves. Based on measured short-term statistics, the large percentage of long waves seem to dominate the wave field and this is consistant with the SOWM's hindcast.

CONCLUSION

Developing nearshore wave climate is a complex procedure. It is not only affected by the shoreline structure, bottom topography, but also by the offshore wind and wave conditions and the path of approaching waves. The wave climate of Kings Bay, Georgia and Cape Canaveral, Florida has been developed. The offshore hindcast data over a period of 15 years from SOWM has been transformed to the nearshore zone. The transformation method takes into account the effects of the Gulf Stream at the offshore zone and shallow water shoaling and refraction at the nearshore zone. The results have been compared with the field measured data and short-term statistics with good agreement. The effect of the Gulf Stream on crossing waves should be divided into two categories, i.e., long waves and local wind waves. The refraction of long waves can be predicted by using ray theory. However, to clarify the generation and reflection of waves from the south and southwest directions, further research work or field data is needed. Furthermore, strong current caused local generated wind waves (i.e., short waves) to stop, break, and reorganize. Further field experiments and research work are needed in this area to develop a model to predict the process of wave evolution in the ocean environment which present strong currents.

ACKNOWLEDGMENTS

The assistance in computer programming for data reduction by Ms. D. Gentile of ORI, Inc. is acknowledged by the authors. Further assistance in data reduction by Ms. B. Simon of DTRC is also acknowledged. The field data are provided by the Coastal and Ocean Engineering Department of the University of Florida (UF). Special thanks to Mr. S. Schofield from UF for his effort on field data analysis and to Ms. S. Bales of DTRC, project manager of this work, for her constant encouragement.

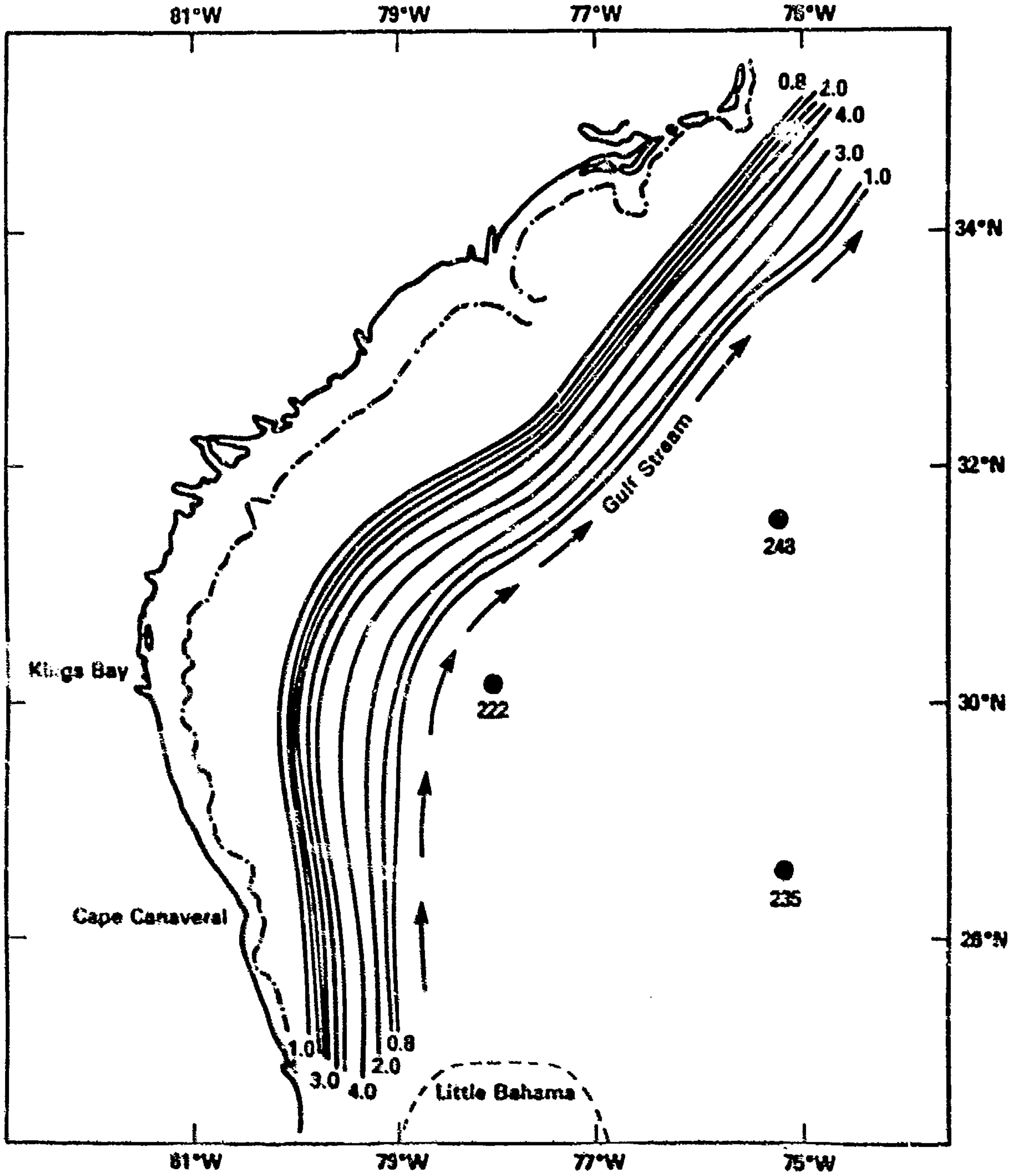


Fig. 1. Map showing SOWM grid points used by SWWM at Kings Bay and Cape Canaveral, where the Gulf Stream speeds are indicated in knots.

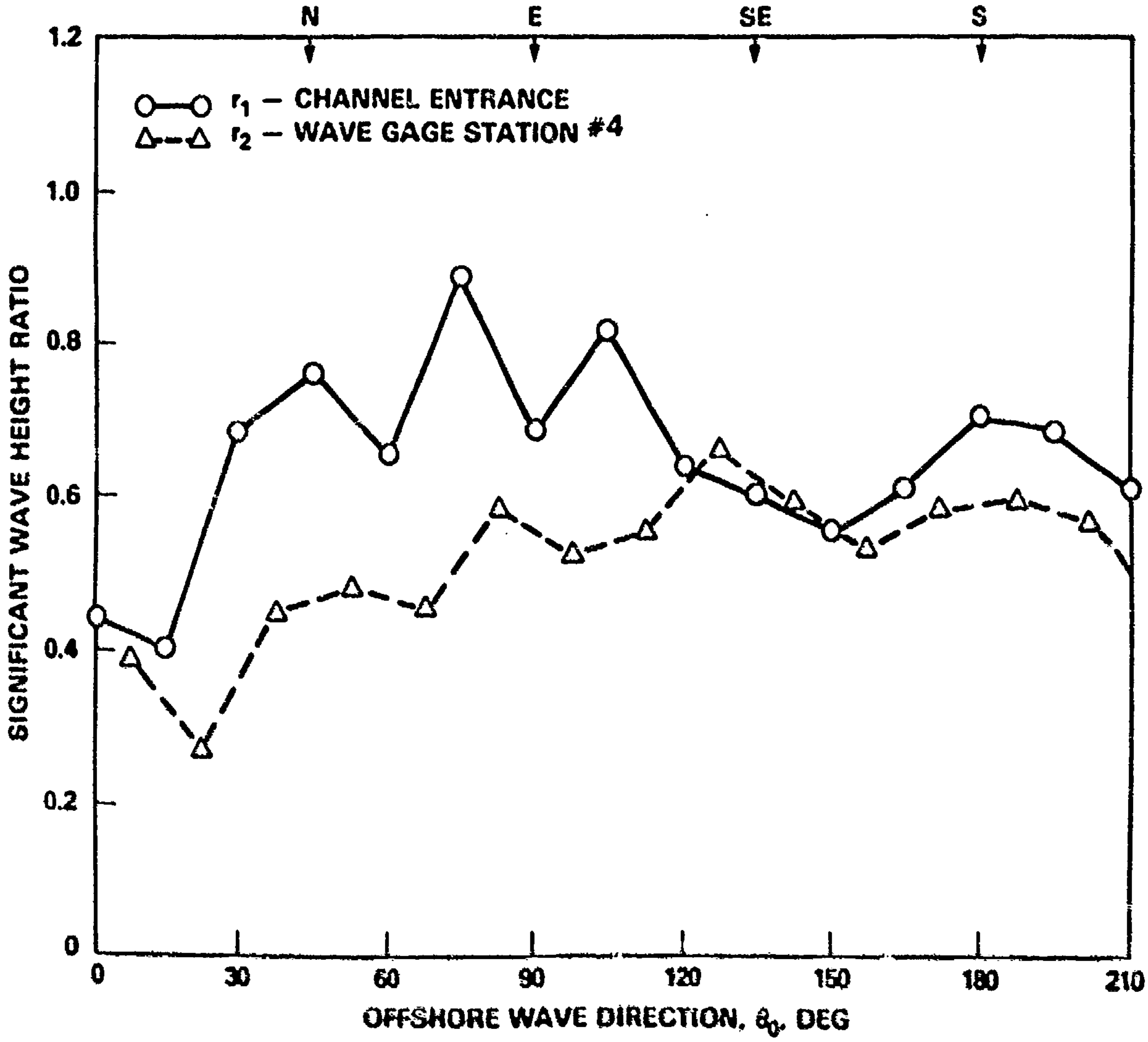


Fig. 2. Ratio of deep water significant wave height to shallow water significant wave height at Cape Canaveral.

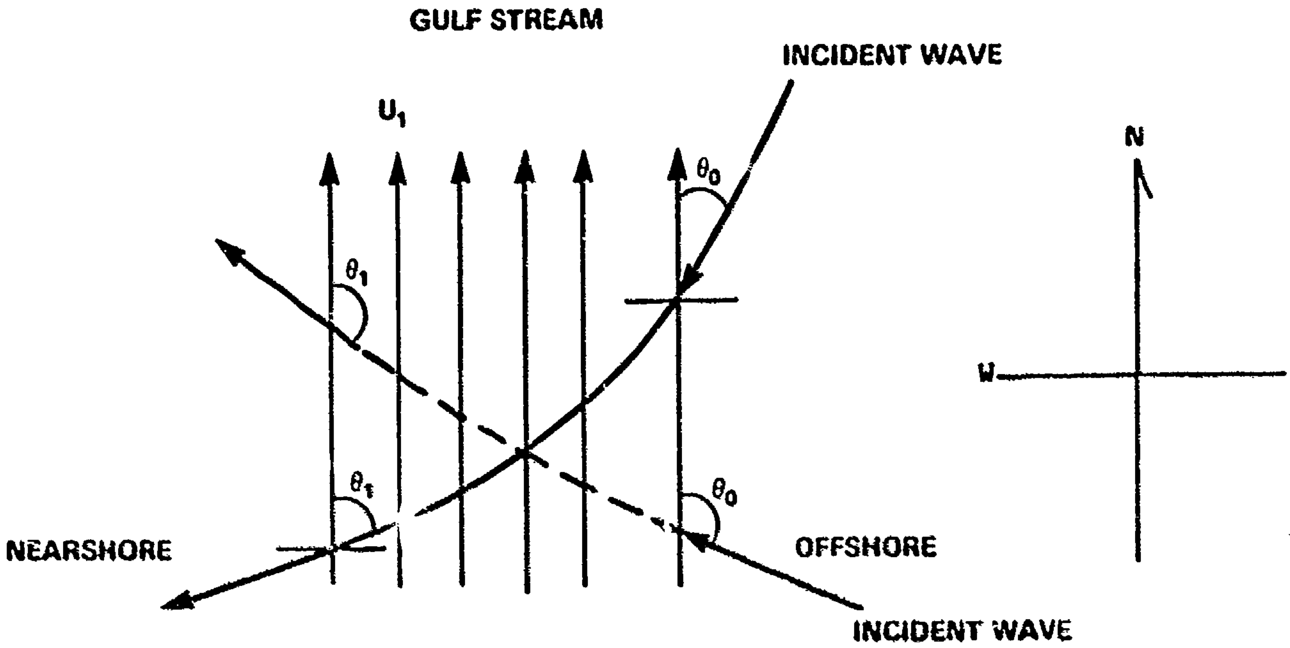


Fig. 3. Change in water direction by the Gulf Stream where θ_0 is incident wave direction and θ_1 is predicted wave direction.

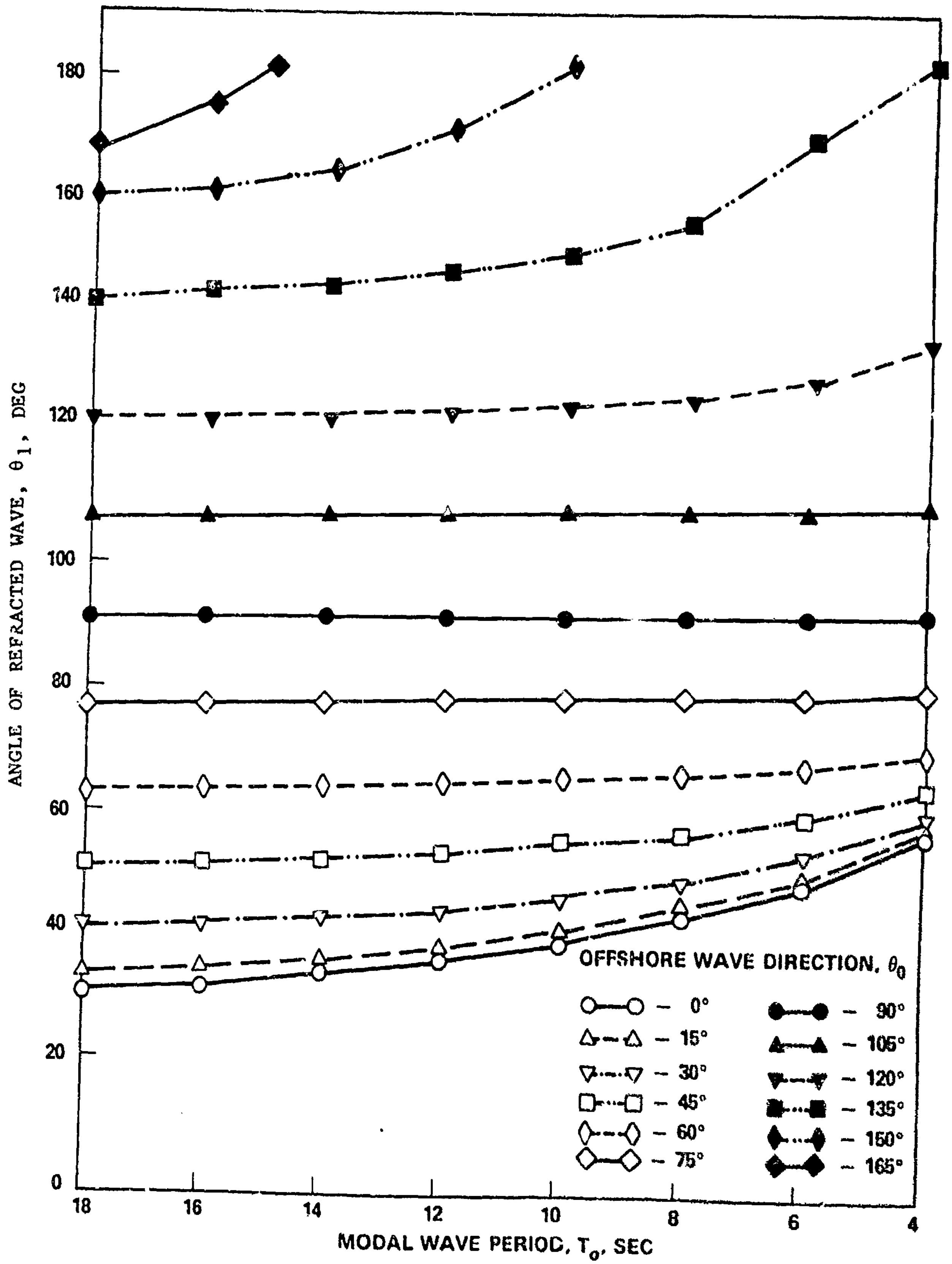


Fig. 4. Angle of refracted wave (θ_1) after crossing the Gulf Stream at Cape Canaveral.

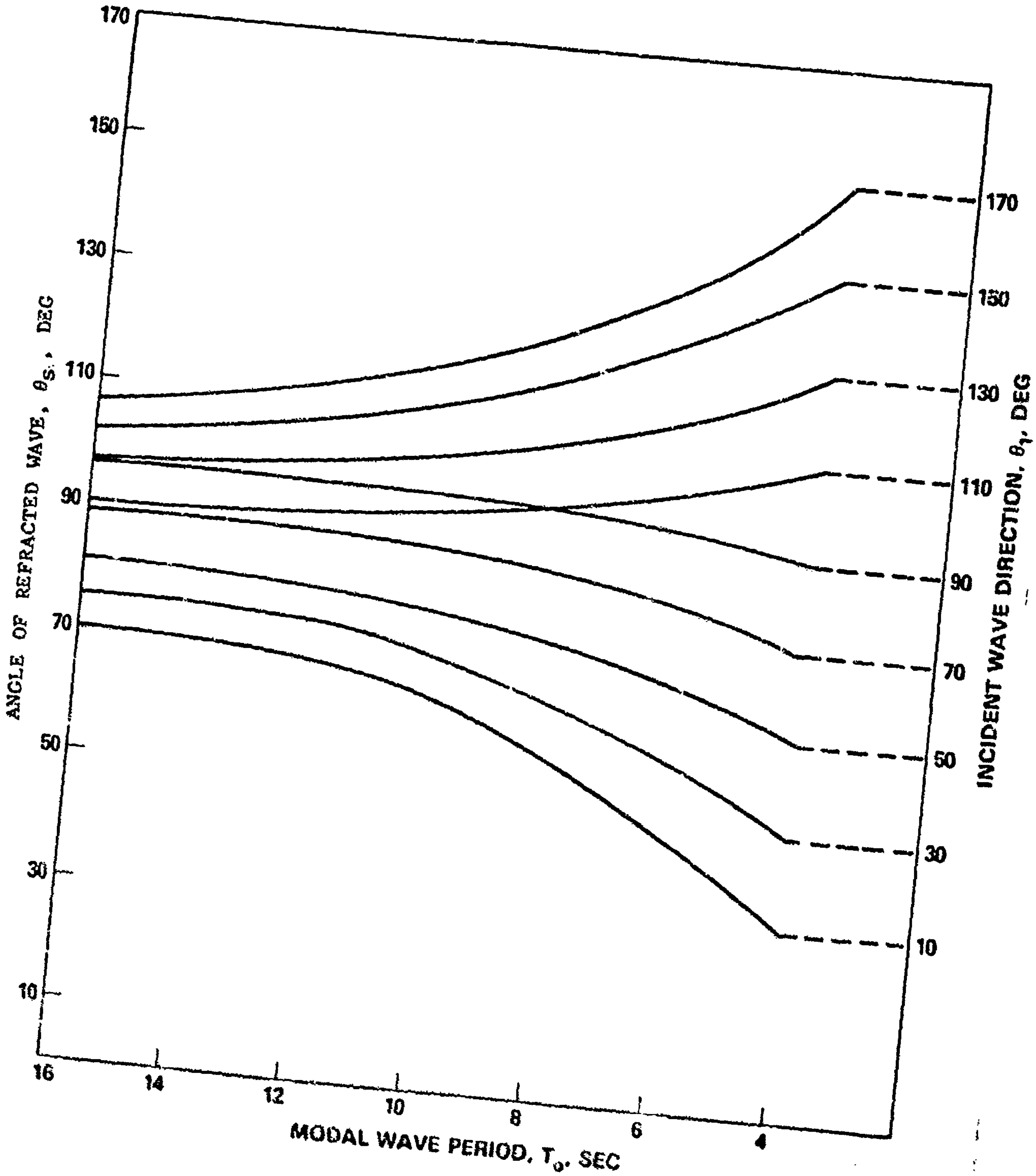


Fig. 5. Angle of refracted wave as computed by SWWM at Cape Canaveral.

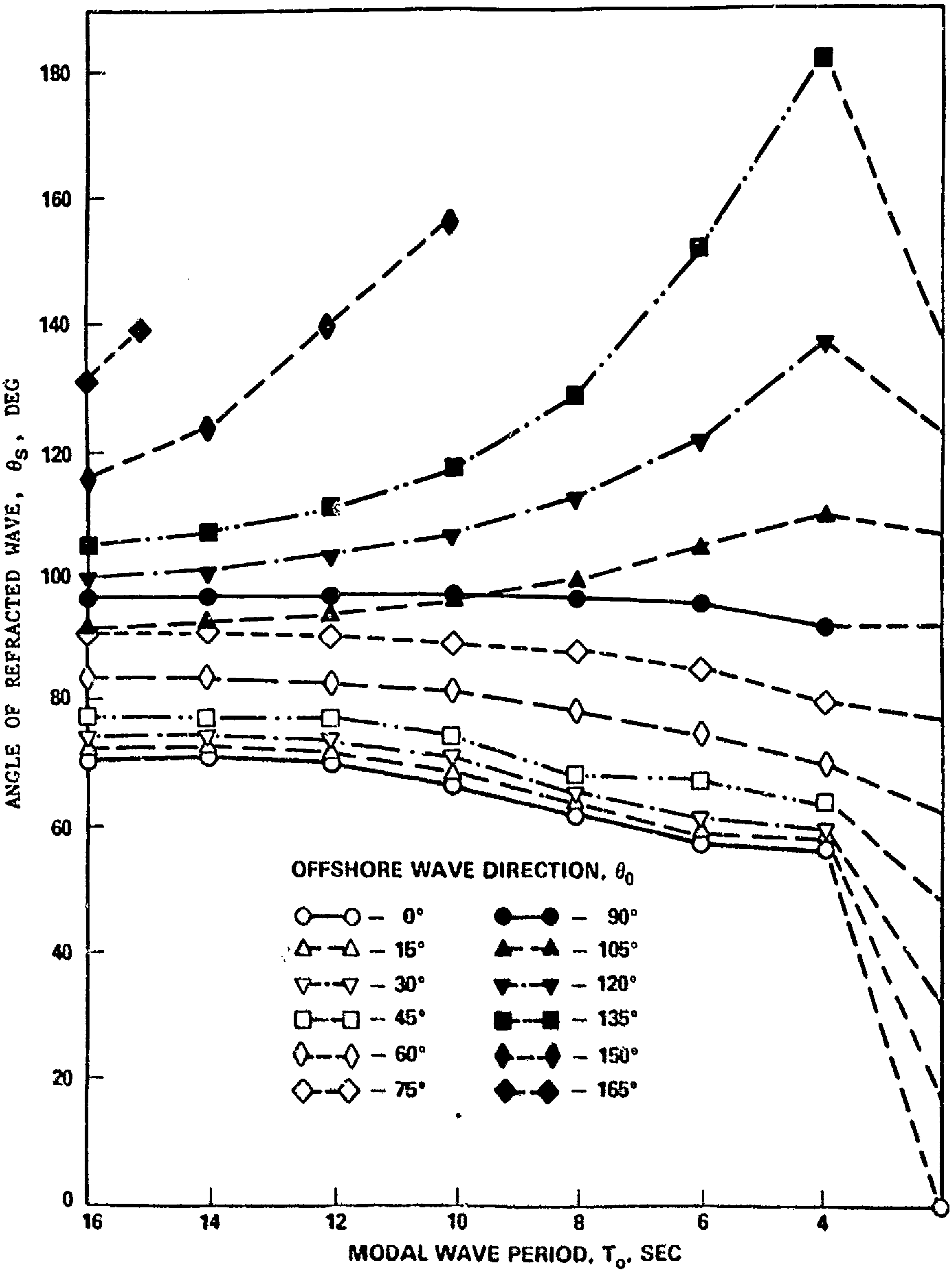


Fig. 6. An... of refracted wave (θ_s) due to the effects of Gulf Stream and shoaling at the channel entrance of Cape Canaveral.

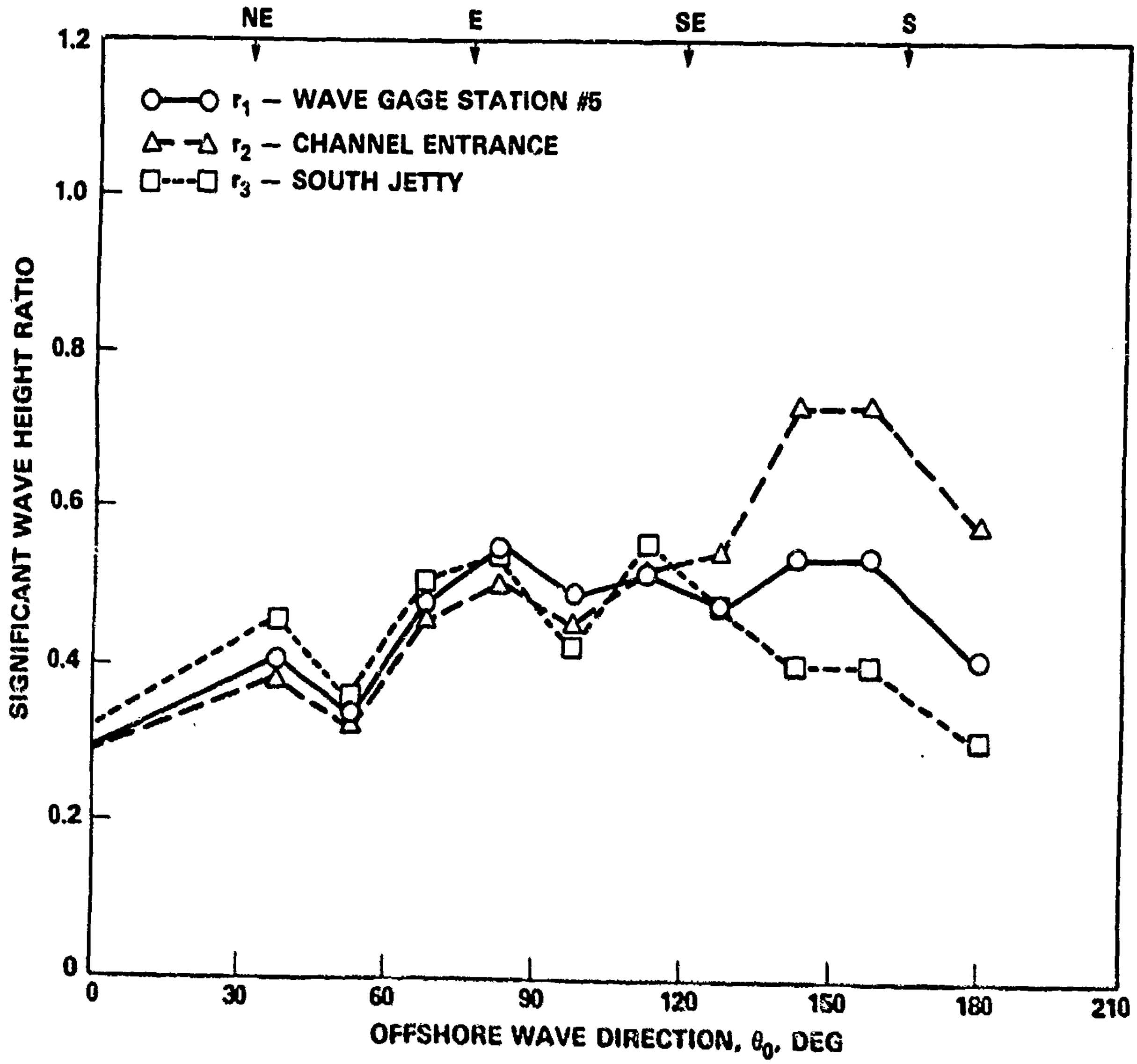


Fig. 7. Ratio of deep water significant wave height to shallow water significant wave height at Kings Bay.

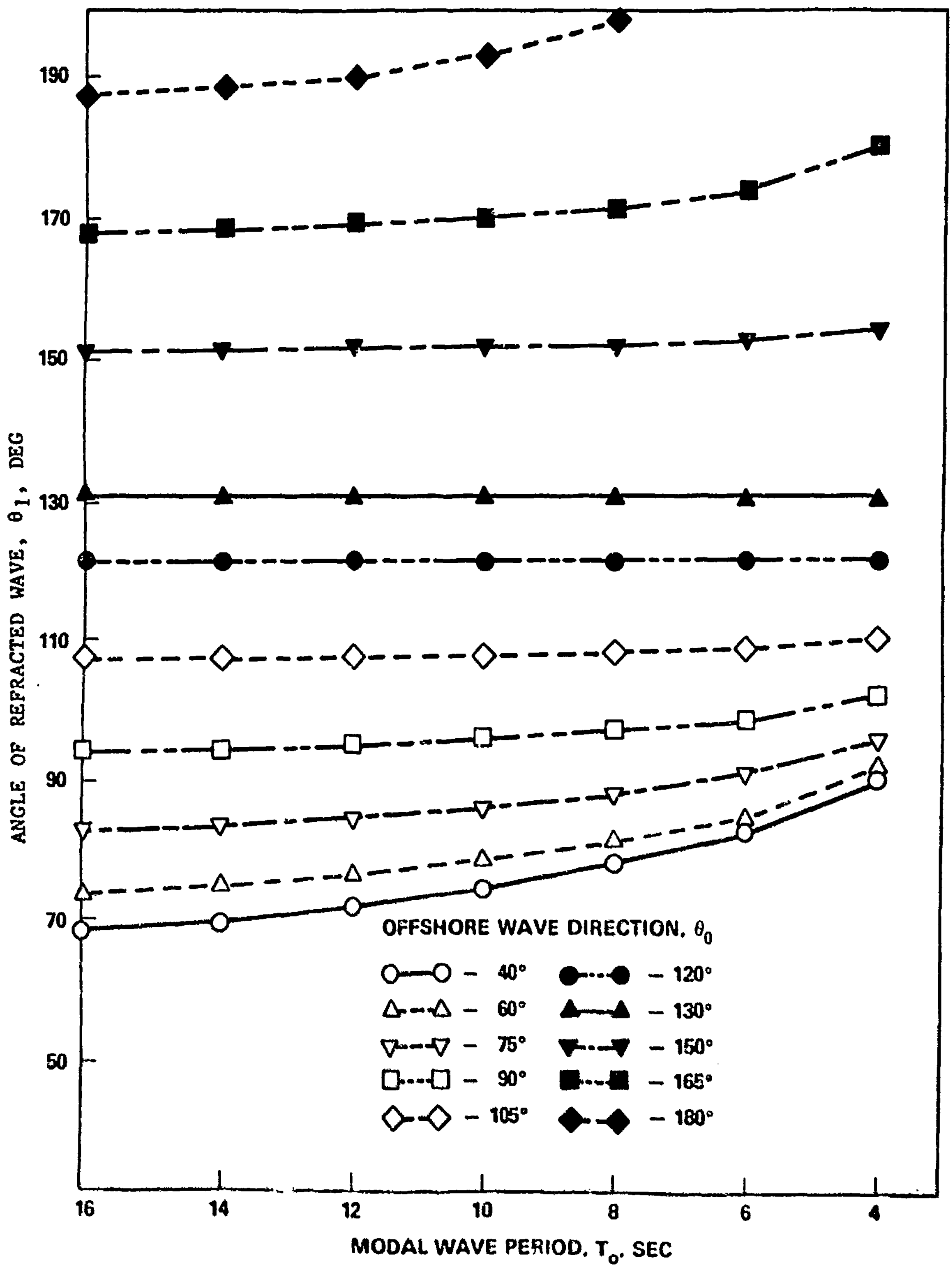


Fig. 8. Angle of refracted wave (θ_1) after crossing the Gulf Stream at Kings Bay.

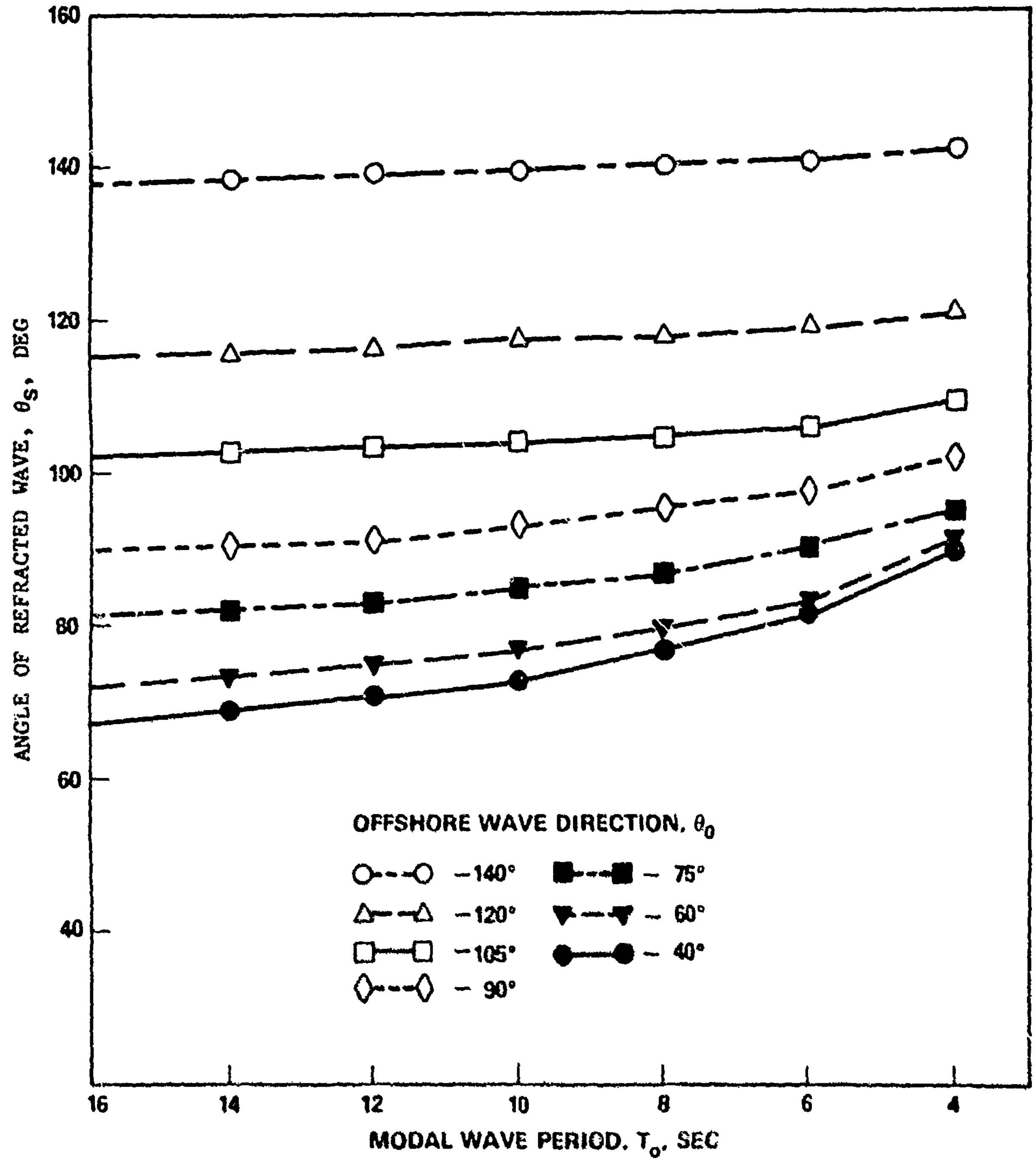


Fig. 9. Angle of refracted wave (θ_S) due to the Effects of Gulf Stream and Shoaling at the Channel Entrance of Kings Bay.

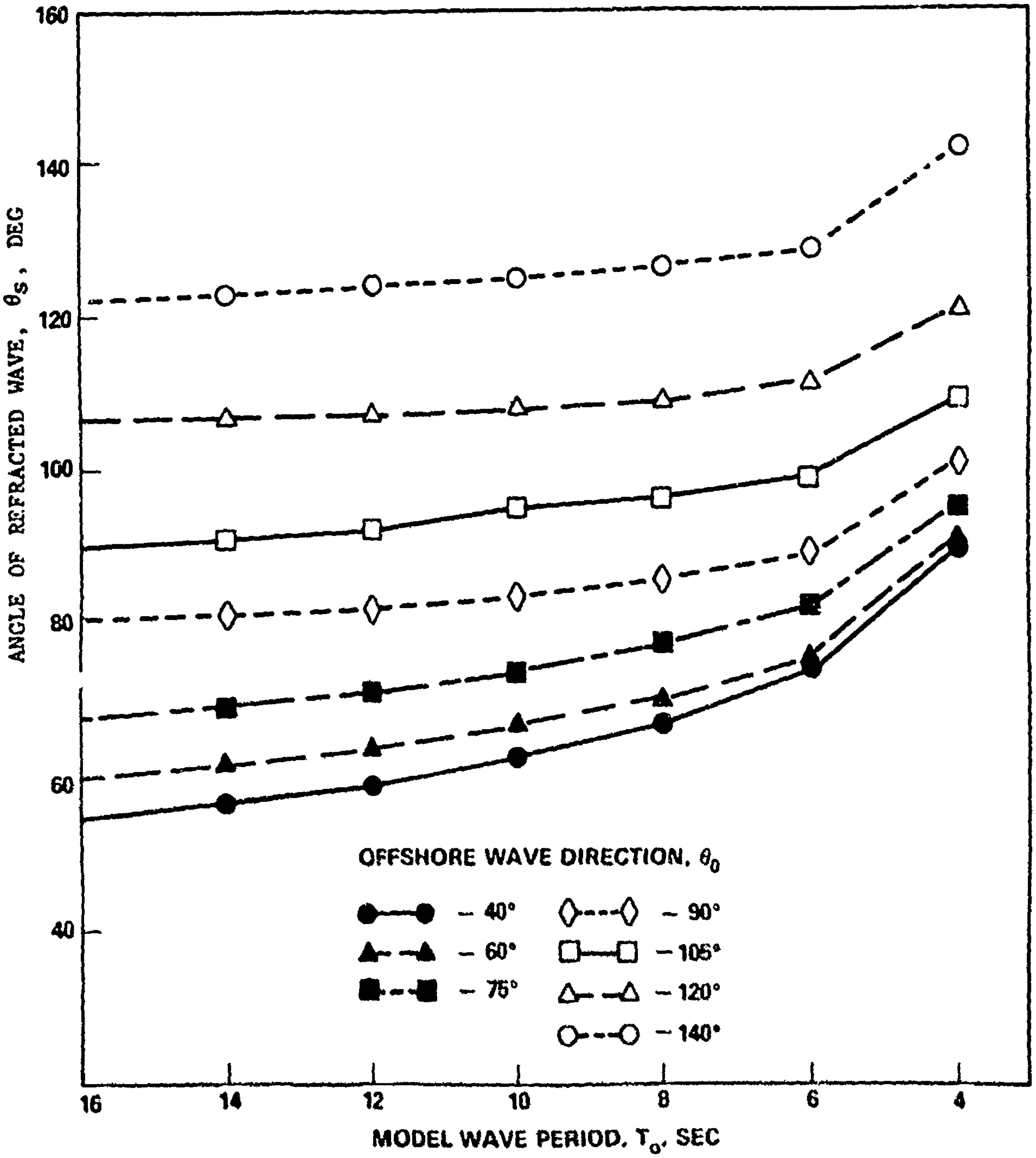


Fig. 10. Angle of refracted wave (θ_S) due to the Effects of Gulf Stream and Shoaling at the South Jetty of Kings Bay.

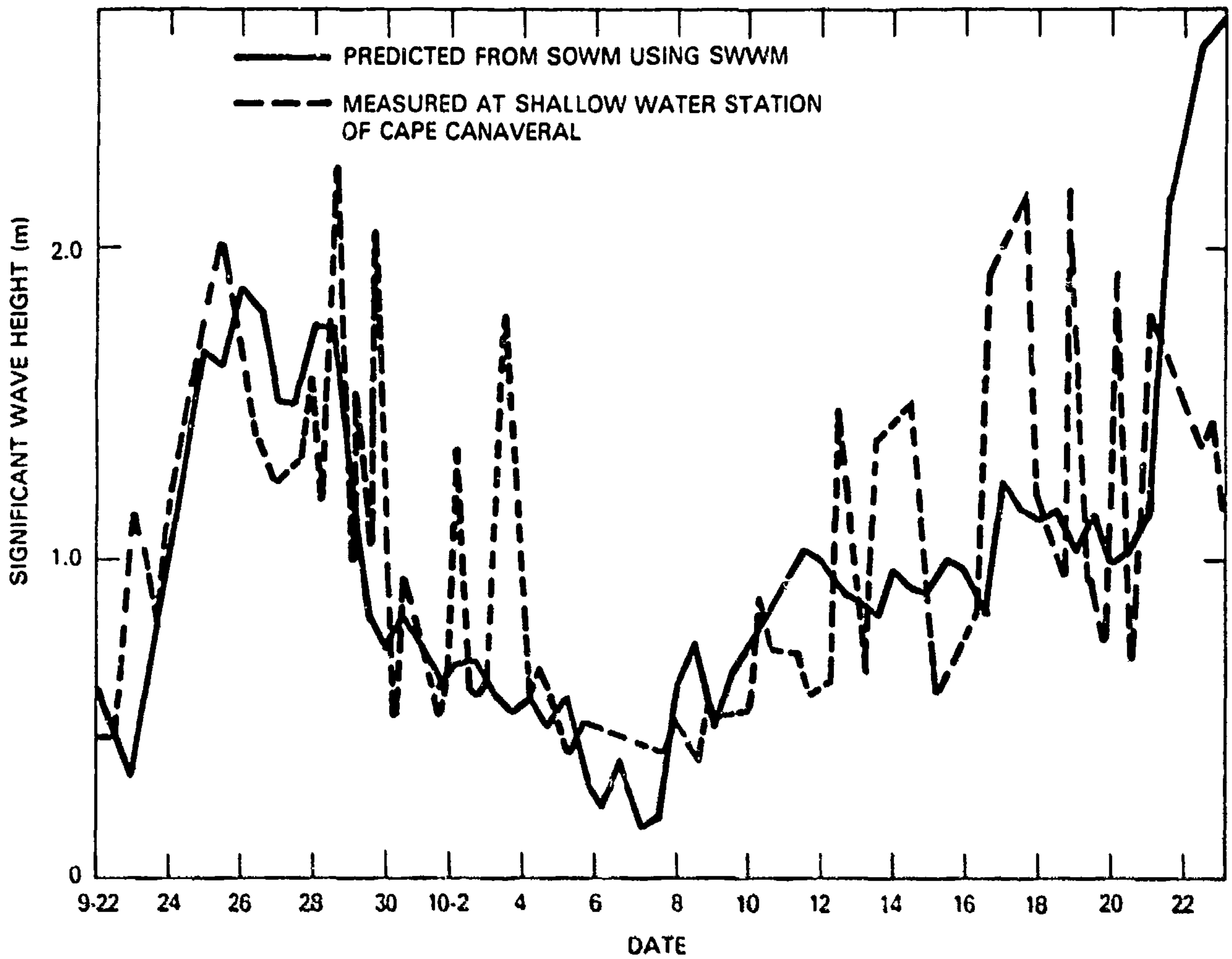


Fig. 11. Comparison from Hindcast SOWM data with measured data at Cape Canaveral of Sensor B during September of '83.

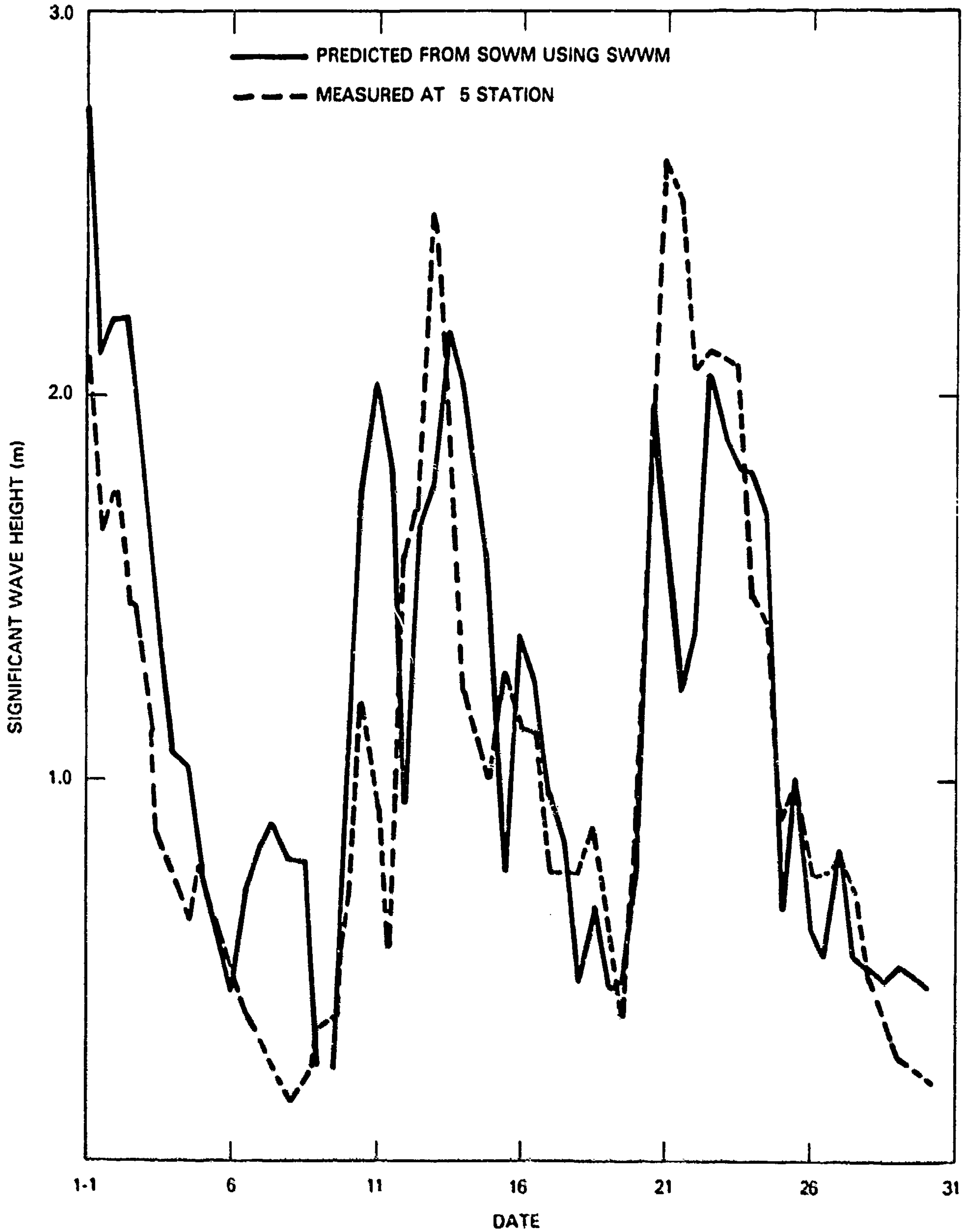


Fig. 12. Comparison from Hindcast SOWM data with measured data at Kings Bay, Station #5 during January of '84.

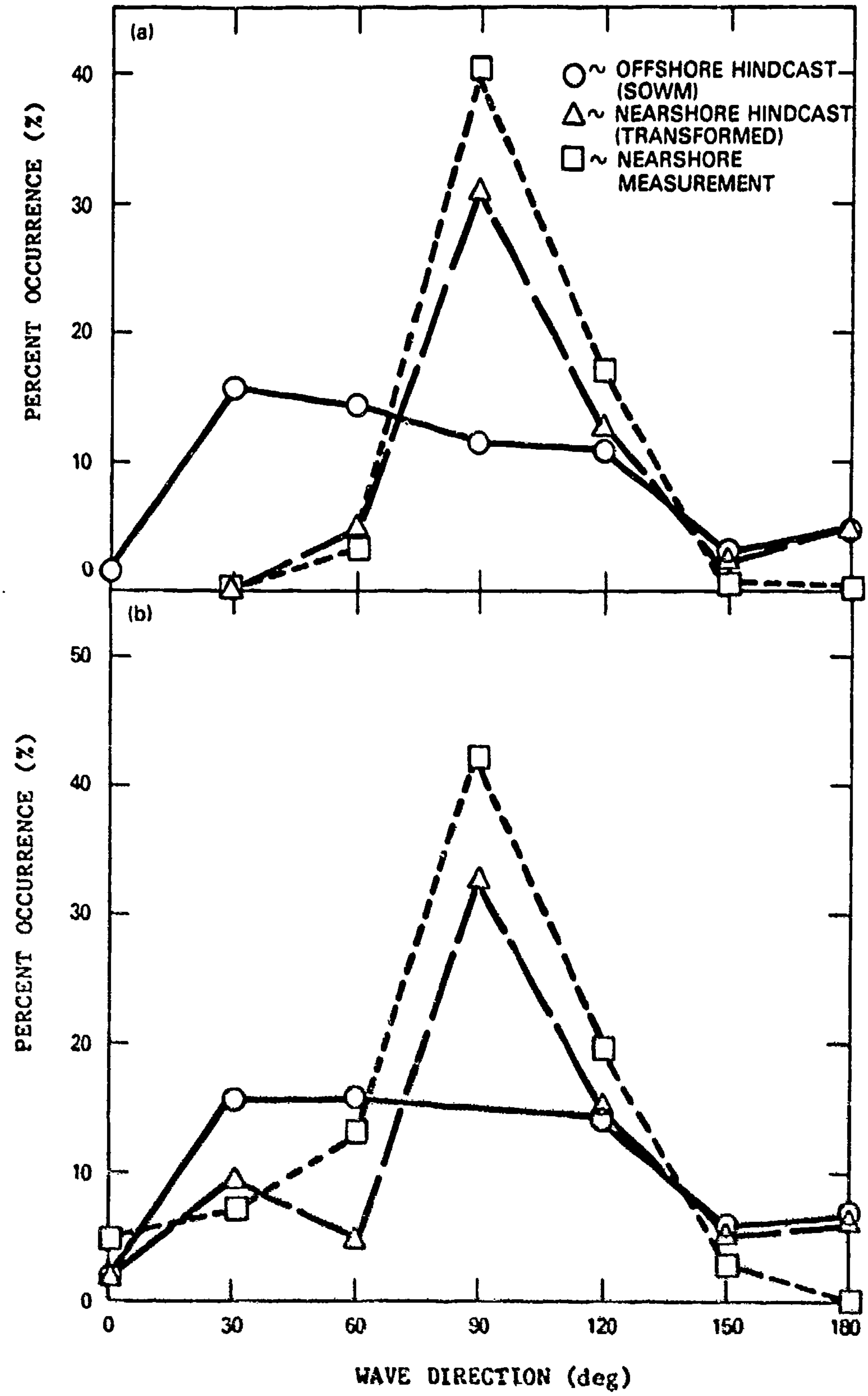


Fig. 13. Comparison of measured and hindcast wave direction statistics of winter '84 at Kings Bay, where (a) for long waves, (b) all waves.

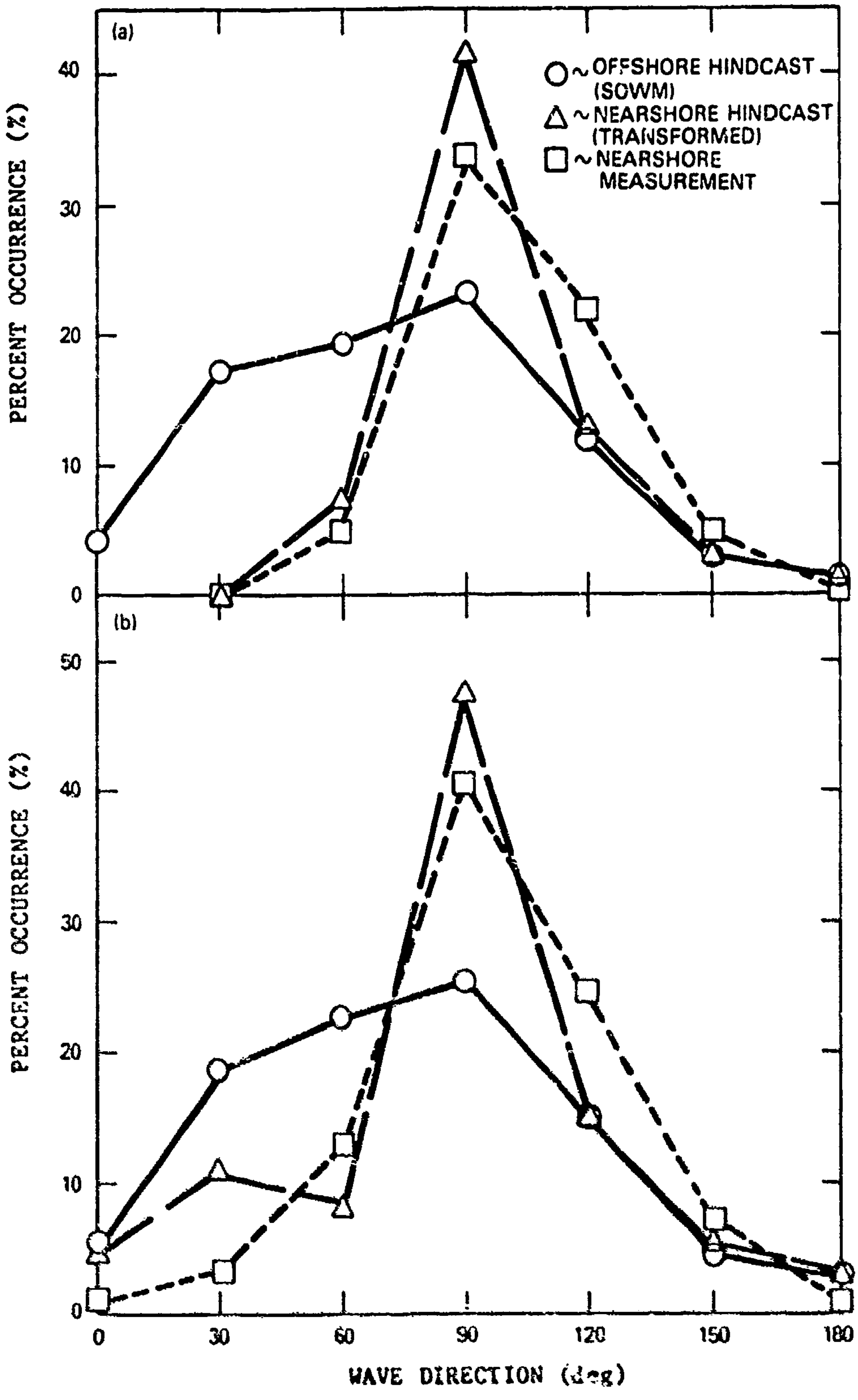


Fig. 14. Comparison of measured and hindcast wave direction statistics of fall '84 at Kings Bay, where (a) long waves only, (b) all waves.

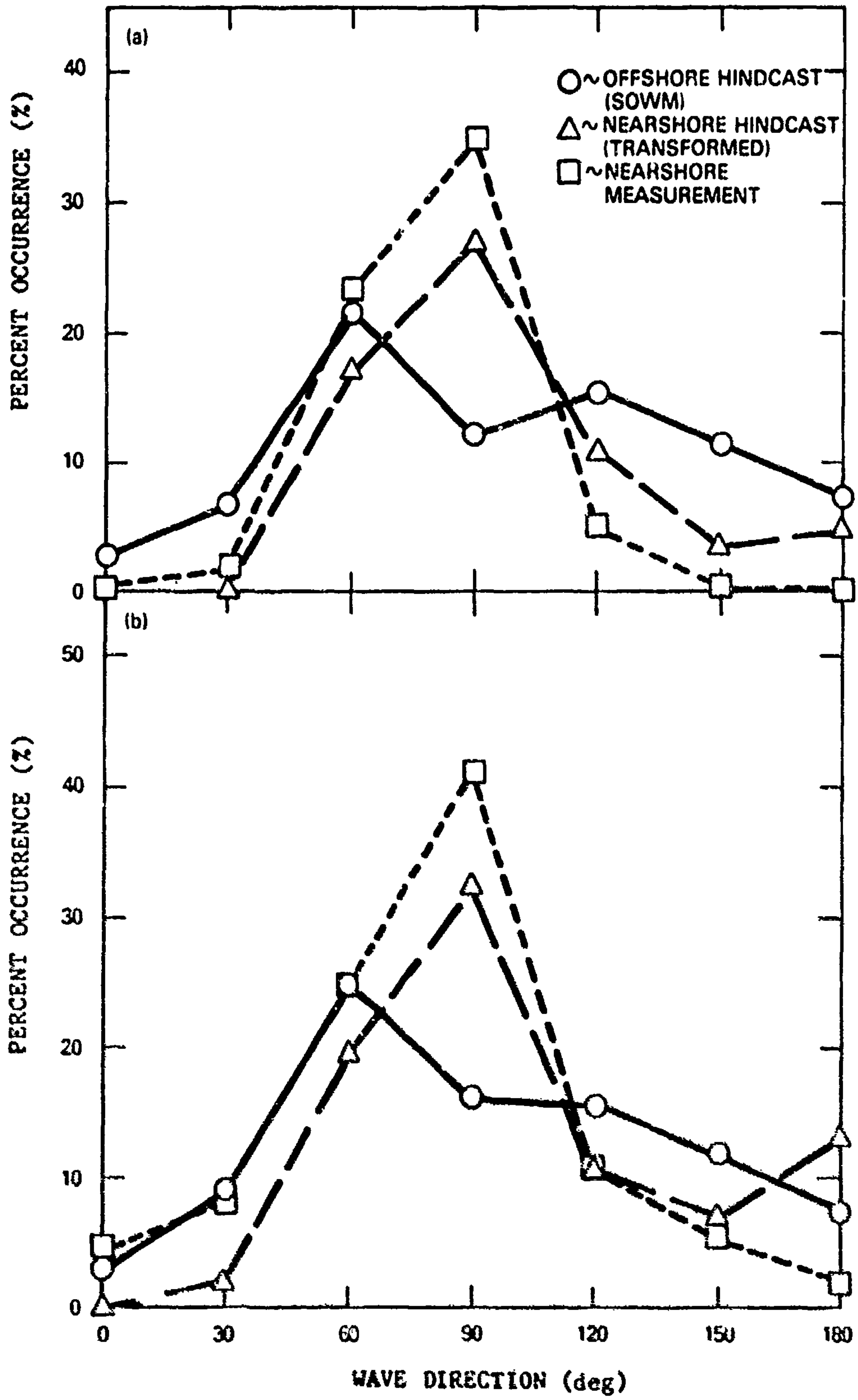


Fig. 15. Comparison of measured and hindcast wave direction statistics of winter '85 at Cape Canaveral, (a) long waves only, (b) all waves.

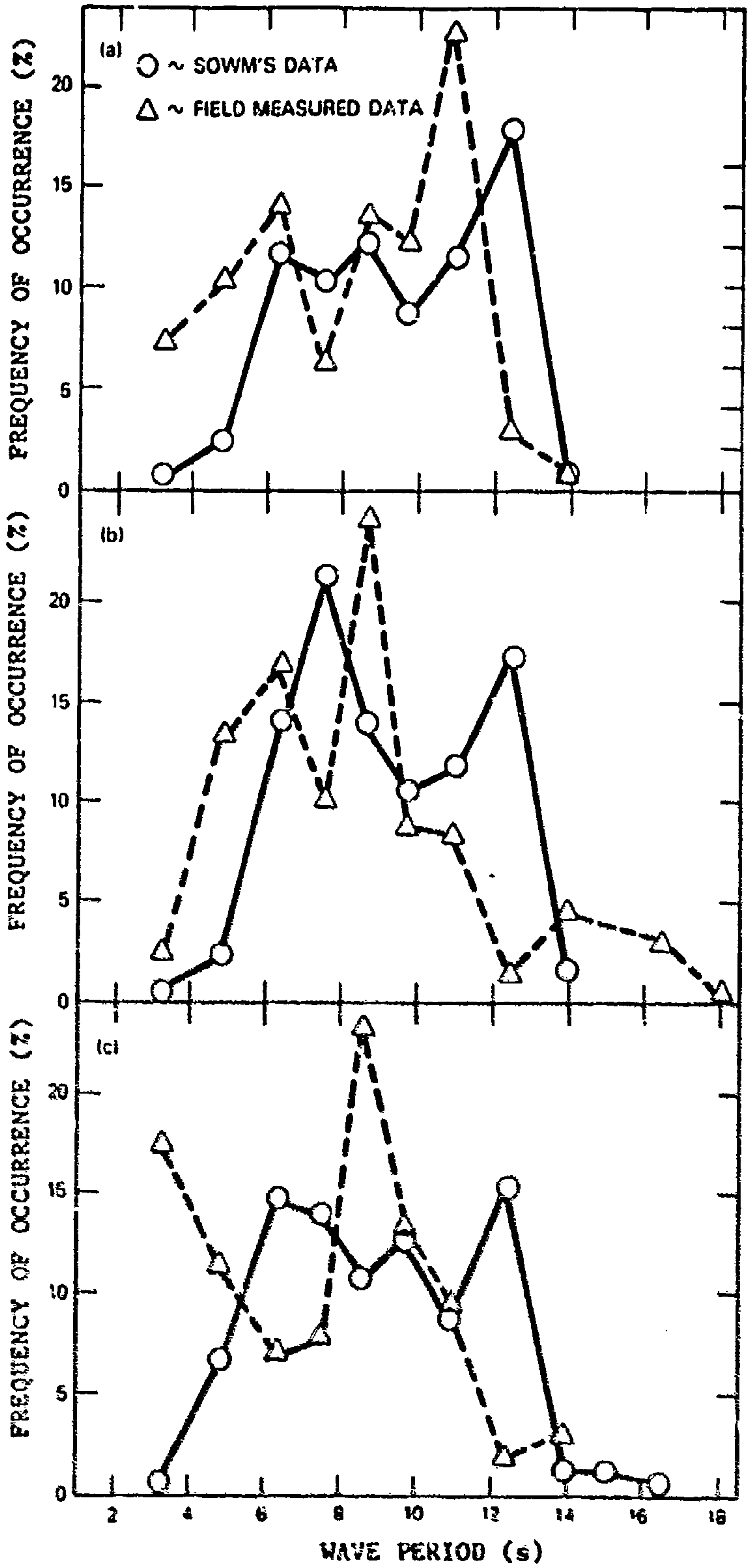


Fig. 16. Comparison of measured and hindcast wave period statistics, where (a) winter of '84 at Kings Bay, (b) fall of '84 at Kings Bay, (c) Winter of '85 at Cape Canaveral.

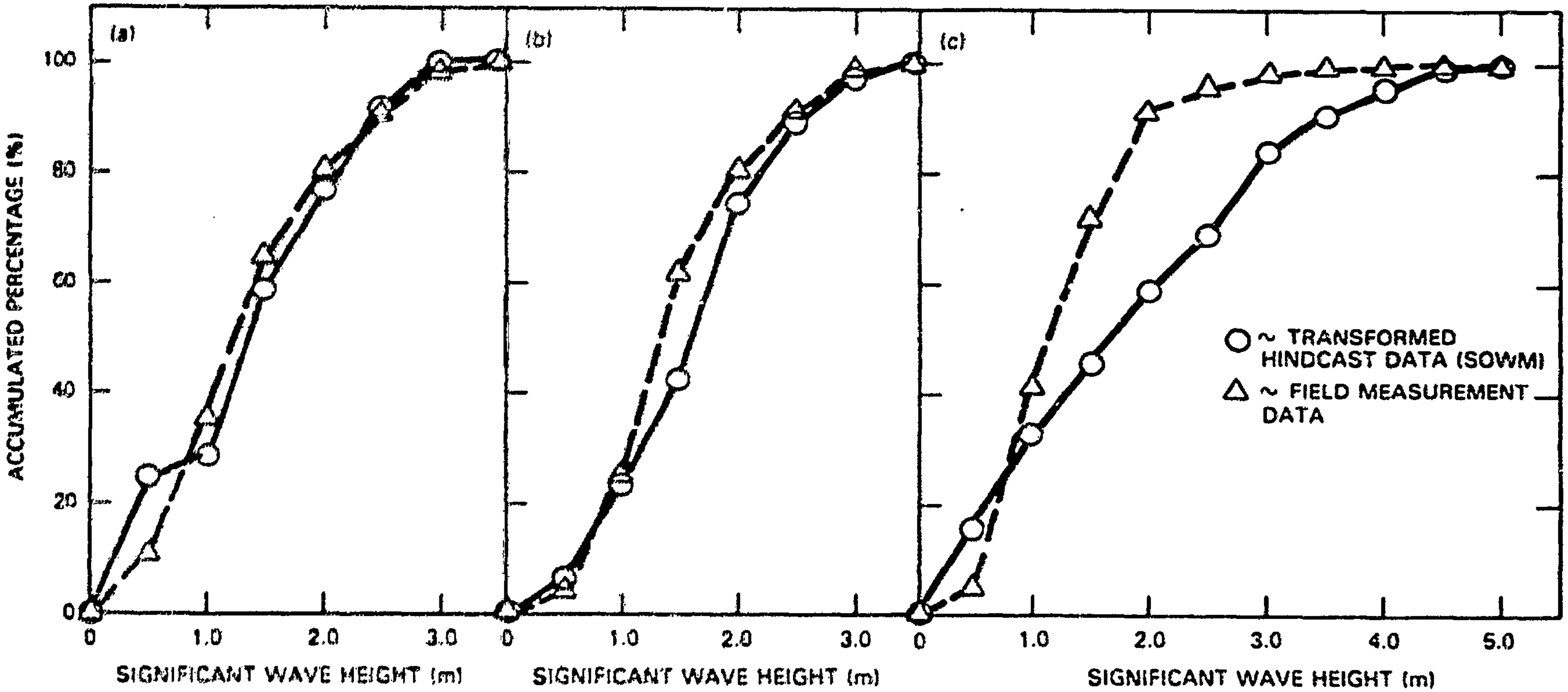


Fig. 17. Comparison of measured and hindcast wave height statistics, where (a) winter of '84 at Kings Bay, (b) Fall of '84 at Kings Bay, (c) winter of '85 at Cape Canaveral.

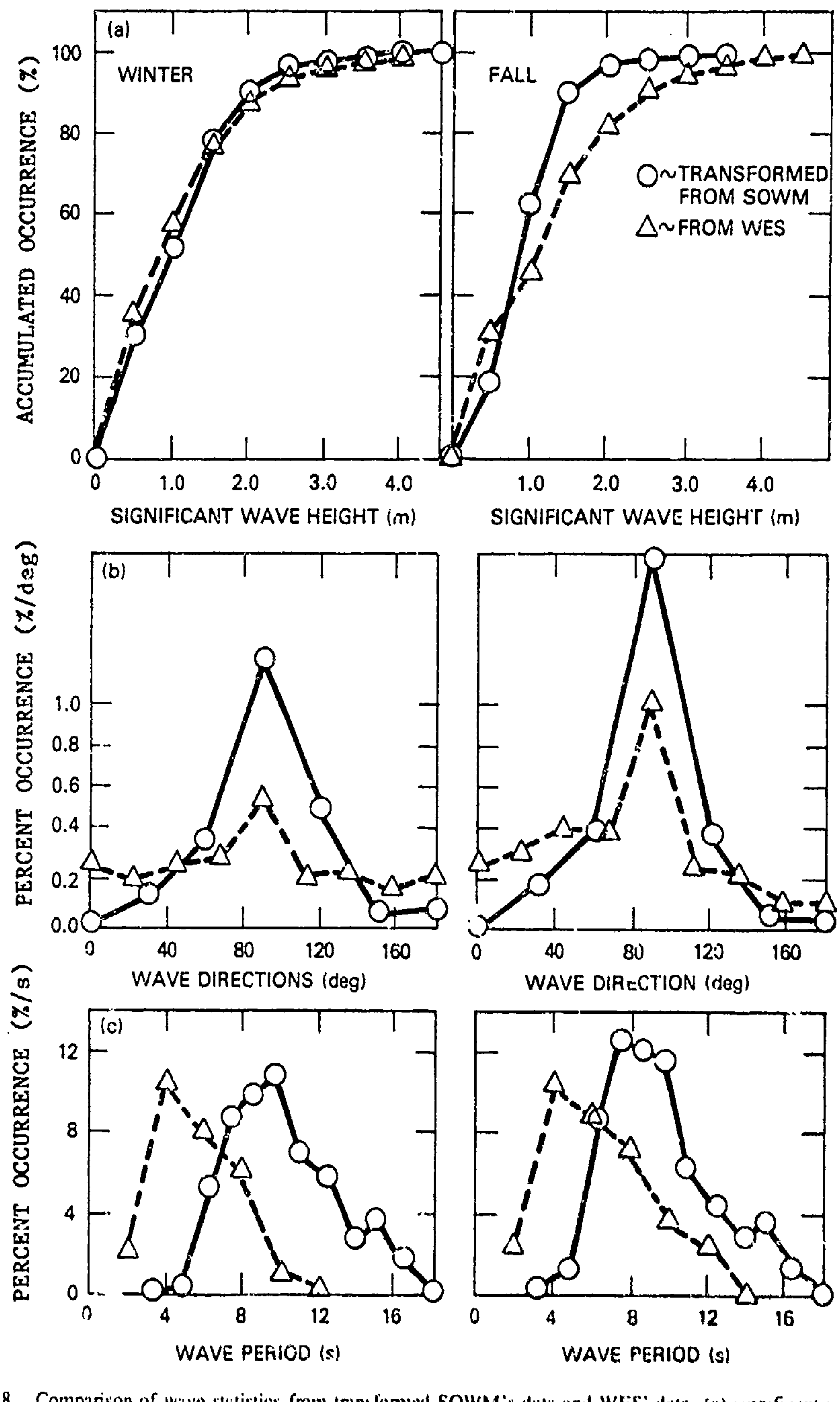


Fig. 18. Comparison of wave statistics from transformed SOWM's data and WES' data. (a) significant wave height, (b) wave direction and (c) wave period at Kings Bay, Georgia during winter and fall.

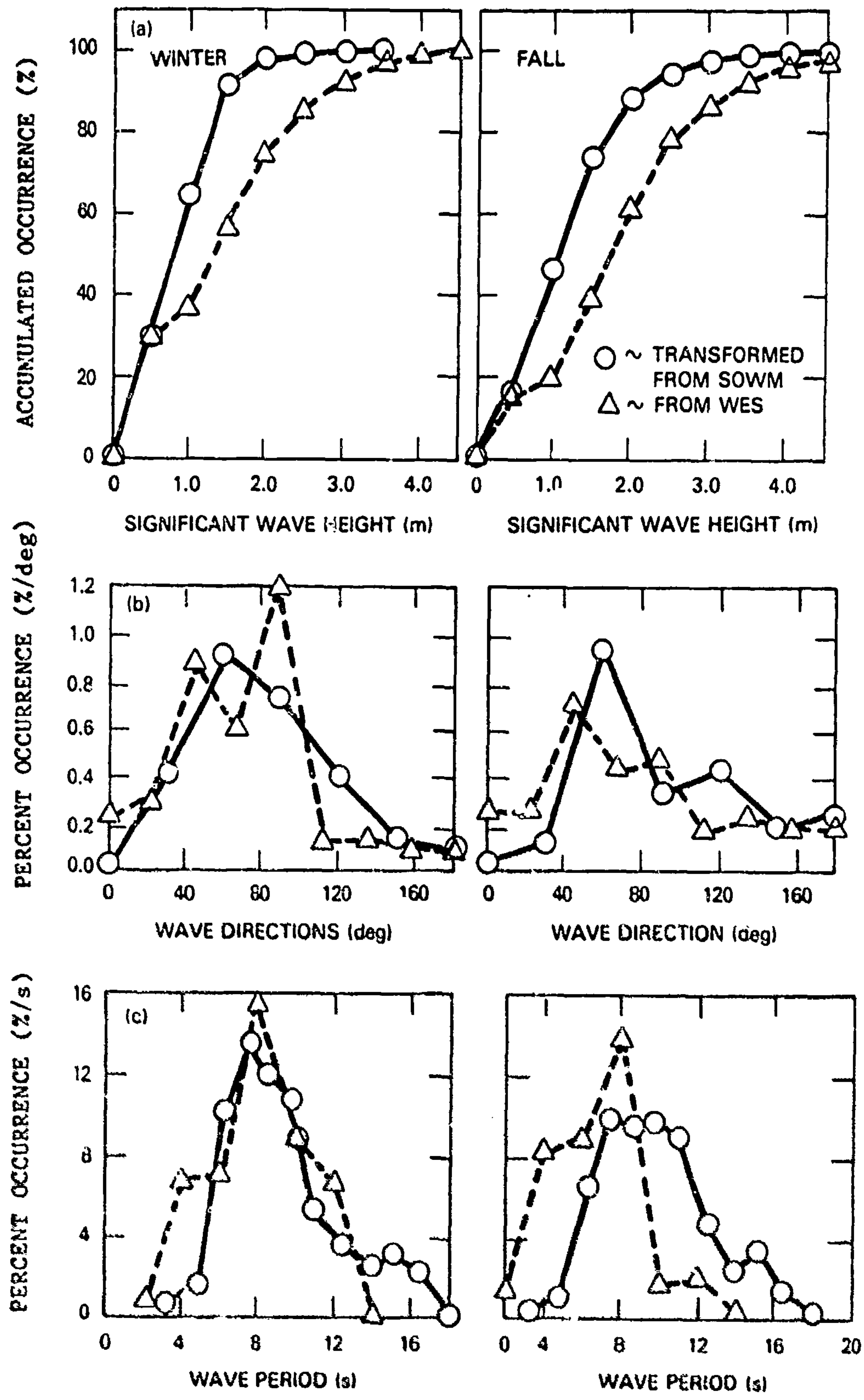


Fig. 19. Comparison of wave statistics from transformed SOWM's data and WES' data. (a) significant wave height, (b) wave direction and (c) wave period at Cape Canaveral, Florida during winter and fall

APPENDIX A

OFFSHORE WIND AND WAVE CLIMATOLOGY

COMBINED ANNUAL TOTAL SAMPLES 46612

PERCENT: 0 25 50 75 100

SIG. WAVE HEIGHT (M)	3.7	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
10.0																
9.5																
9.0													+			+
8.5												+	+			+
8.0											+		+			+
7.5											+		+		+	+
7.0								+		+	+					+
6.5								+	+	+	+	+	+			+
6.0							+	+	+	+	+	+	+			+
5.5							+	+	+	+	+		+			0.1
5.0						+	+	+	+	+	+	+	+			0.2
4.5						+	0.1	+	+	+	+	+				0.3
4.0					+	0.1	0.2	0.1	+	+	+					0.5
3.5					+	0.4	0.3	0.1	+	+	+					1.0
3.0				+	0.4	0.8	0.4	0.2	+	0.1	+	+				2.1
2.5				0.2	1.5	0.9	0.3	0.4	0.1	0.2	+	+				3.7
2.0			+	2.0	1.9	1.0	0.6	0.5	0.2	0.2	0.1	+				6.7
1.5		+	2.1	3.4	2.2	1.5	1.0	0.8	0.5	0.4	0.2	+	+			12.2
1.0		1.2	4.4	3.5	3.5	3.1	1.8	1.3	0.6	0.9	0.3	+				20.6
.5	0.4	1.1	8.3	7.8	5.0	3.5	3.0	2.0	1.0	1.8	0.6	+	+			34.1
0.0	1.0		3.6	3.8	2.1	3.4	1.3	1.3	0.5	0.8	0.3	+	+			18.3
TOTALS	1.3	2.2	18.4	20.7	19.5	16.8	9.0	7.1	3.4	4.3	1.8	0.3	+		+	100.0

MODAL WAVE PERIOD (SEC)

Figure A-COMB-1-1 Significant Wave Height vs. *Modal Wave Period*

COMBINED ANNUAL TOTAL SAMPLES 46612

SIG. WAVE HEIGHT (M)	0	30	60	90	120	150	180	210	240	270	300	330	TOTALS
10.0													
9.5													
9.0		+											+
8.5		+											+
8.0	+	+											+
7.5	+	+									+		+
7.0			+								+		+
6.5		+	+	+									+
6.0	+	+	+	+			+	+		+			+
5.5	+	+	+	+			+		+	+	+		0.1
5.0	+	+	+	+			+	+	+	+	+		0.2
4.5	+	+	+	+			+	+	+	+	+	+	0.3
4.0	+	+	0.2	+	+		+	+	+	+	+	+	0.5
3.5	0.1	0.2	0.3	0.1	+		+	+	+	+	+	+	1.0
3.0	0.3	0.4	0.5	0.1	+	+	+	0.1	0.2	0.1	0.1	+	2.1
2.5	0.5	0.7	0.7	0.4	+	+	+	0.3	0.4	0.2	0.1	+	3.7
2.0	1.0	1.3	1.1	0.6	0.3	+	0.2	0.5	0.6	0.5	0.3	0.2	6.7
1.5	1.4	2.1	1.7	1.1	1.8	0.2	0.3	1.0	1.1	0.9	0.5	0.3	12.2
1.0	1.8	3.0	1.7	1.7	6.3	0.5	0.4	1.5	1.6	1.0	0.6	0.5	20.6
.5	2.2	3.7	1.8	2.8	15.7	1.7	0.5	1.6	1.8	1.1	0.7	0.7	34.1
0.0	0.7	1.9	0.7	2.8	7.1	2.4	0.3	0.7	0.7	0.4	0.2	0.4	18.3
TOTALS	8.2	13.7	8.9	9.8	31.4	4.9	1.8	5.9	6.3	4.3	2.7	2.1	100.0

PRIMARY WAVE DIRECTION

PERCENT

Figure A-COMB-1-2 Significant Wave Height vs. Primary Wave Direction

COMBINED ANNUAL TOTAL SAMPLES 46612

SIG. WAVE HEIGHT (M)	0	5	10	15	20	25	30	35	40	45	50	80	TOTALS
10.0													
9.5													
9.0					+	+	+						+
8.5				+									+
8.0			+				+						+
7.5		+	+	+									+
7.0	+	+	+	+	+								+
6.5	+	+	+	+	+	+	+	+					+
6.0	+	+	+	+	+	+	+	+	+				+
5.5	+	+	+	+	+	+	+	+					0.1
5.0	+	+	+	+	+	+	+	+					0.2
4.5	+	+	+	+	+	+	+	+	+				0.3
4.0	+	+	+	+	0.1	0.2	+	+					0.5
3.5	+	+	0.1	0.1	0.3	0.4	+	+	+				1.0
3.0	+	0.2	0.2	0.4	0.9	0.4	+	+					2.1
2.5	0.1	0.2	0.6	1.0	1.5	0.2	+	+					3.7
2.0	0.3	0.7	1.3	2.9	1.4	0.1	+	+					6.7
1.5	0.6	2.0	3.7	5.3	0.5	+	+						12.2
1.0	2.5	8.0	8.4	2.6	0.2	+							20.6
.5	8.0	18.4	8.4	0.3	+								34.1
0.0	7.5	10.5	0.3										18.3
TOTALS	18.1	36.0	25.2	12.8	4.8	1.5	0.4	+	+				100.0

WIND SPEED AT 19.5 M (KNOTS)

PERCENT: 0, 25, 50, 75, 100

Figure A-COMB-1-3 Significant Wave Height vs. Wind Speed

COMBINED ANNUAL TOTAL SAMPLES 46612

PERCENT 0 50 100

WIND SPEED AT 19.5 M (KNOTS)	0	30	60	90	120	150	180	210	240	270	300	330	TOTALS
80													
50													
45													
40								+					+
35			+	+			+	+	+	+	+		+
30		+	+	+	+		+	+	+	+	+	+	0.4
25	+	0.1	0.2	0.1	+	+	+	0.2	0.3	0.2	0.1	+	1.5
20	0.2	0.5	0.8	0.4	+	+	0.2	0.6	0.8	0.6	0.3	0.3	4.8
15	0.7	1.2	2.2	1.2	0.5	0.3	0.5	1.5	1.9	1.2	0.9	0.7	12.8
10	1.6	2.3	3.4	2.5	1.7	1.3	1.9	3.4	2.8	1.5	1.5	1.5	25.2
5	2.1	2.6	3.2	3.5	3.6	3.7	4.7	4.7	3.0	1.8	1.5	1.6	38.0
0	1.0	1.3	1.5	1.8	2.0	2.2	2.3	2.0	1.3	1.1	1.0	0.9	18.2
TOTALS	5.9	13.1	11.4	9.8	7.9	7.6	9.7	12.6	10.3	8.5	5.3	5.1	100.0

WIND DIRECTION

PERCENT: 0, 25, 50, 75, 100

Figure A-COMB-1-4 Wind Speed vs. Wind Direction

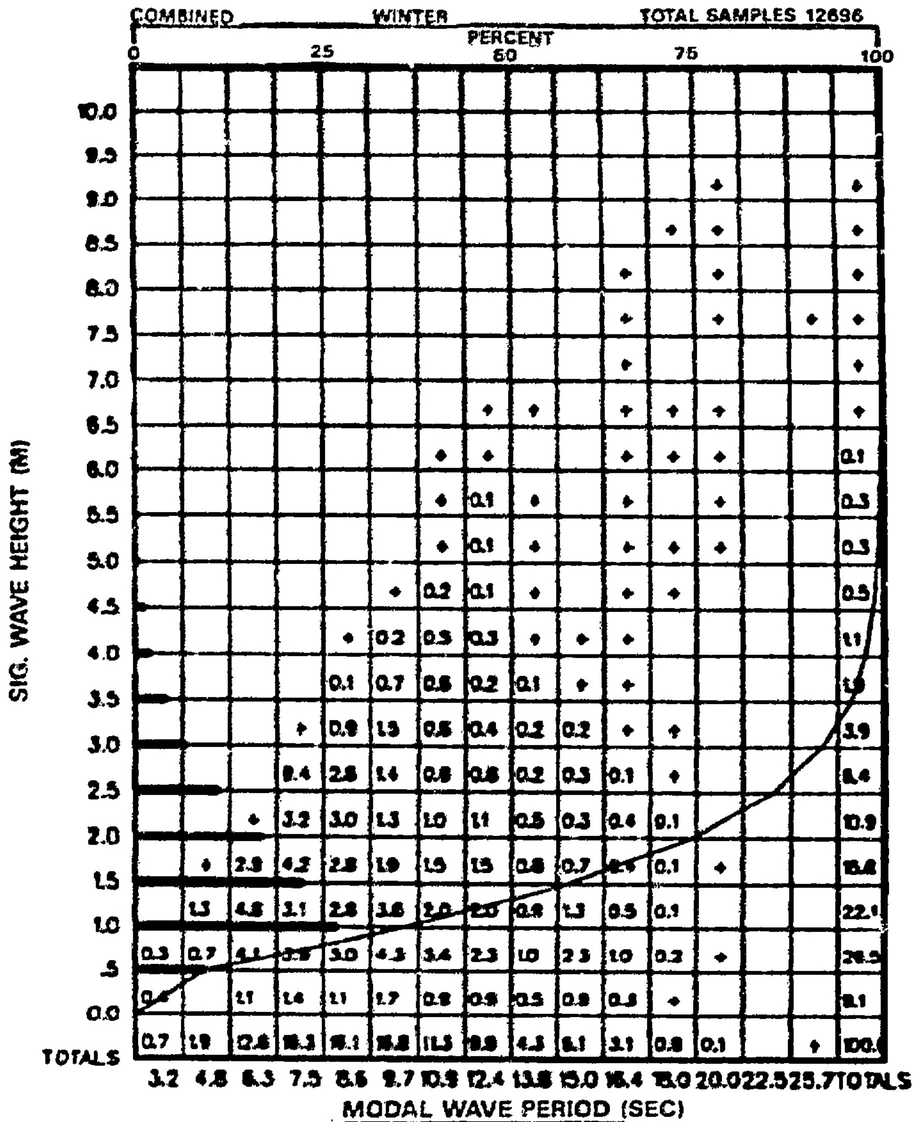


Figure A-COMB-2-1 Significant Wave Height vs. Modal Wave Period

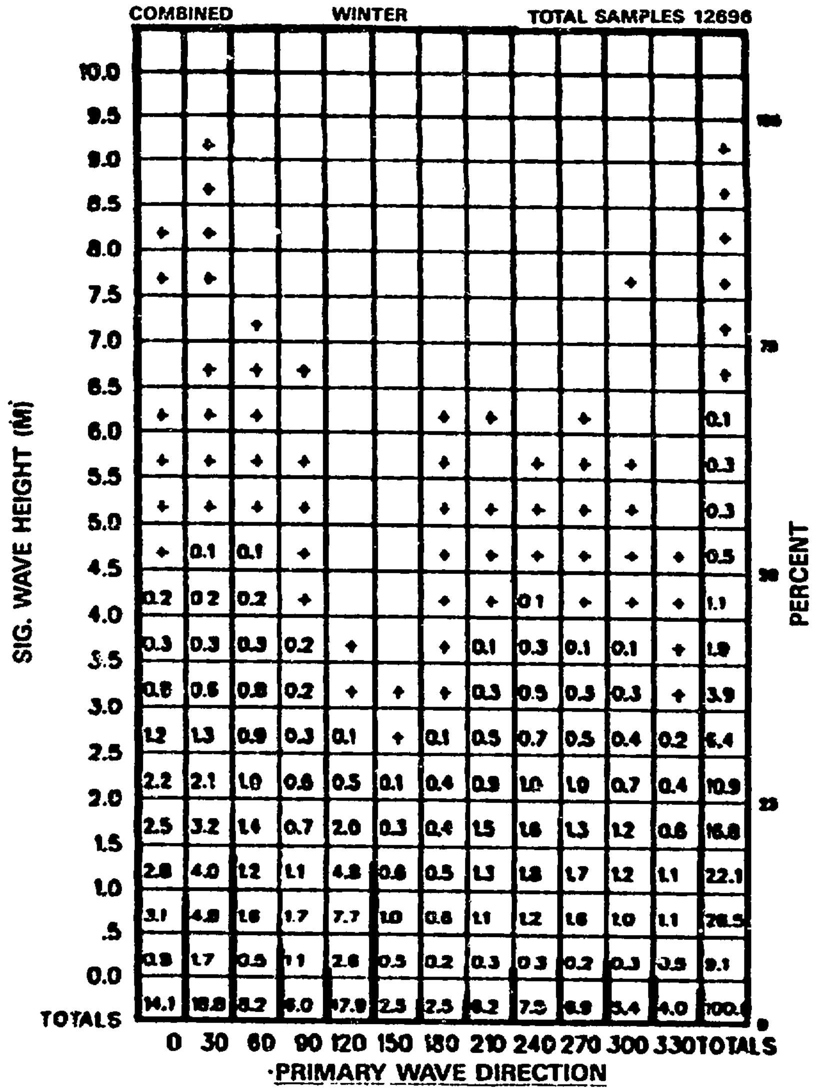


Figure A-COMB-2-2 Significant Wave Height vs. Primary Wave Direction

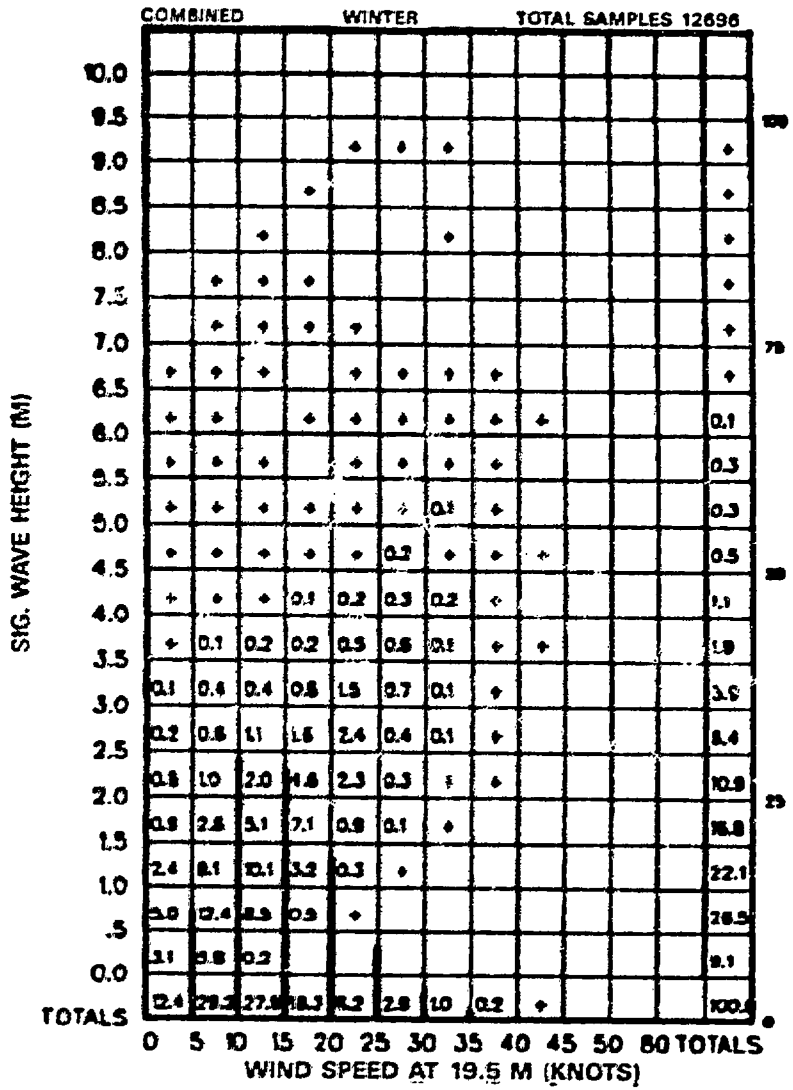


Figure A-COMB-2-3 Significant Wave Height vs. Wind Speed

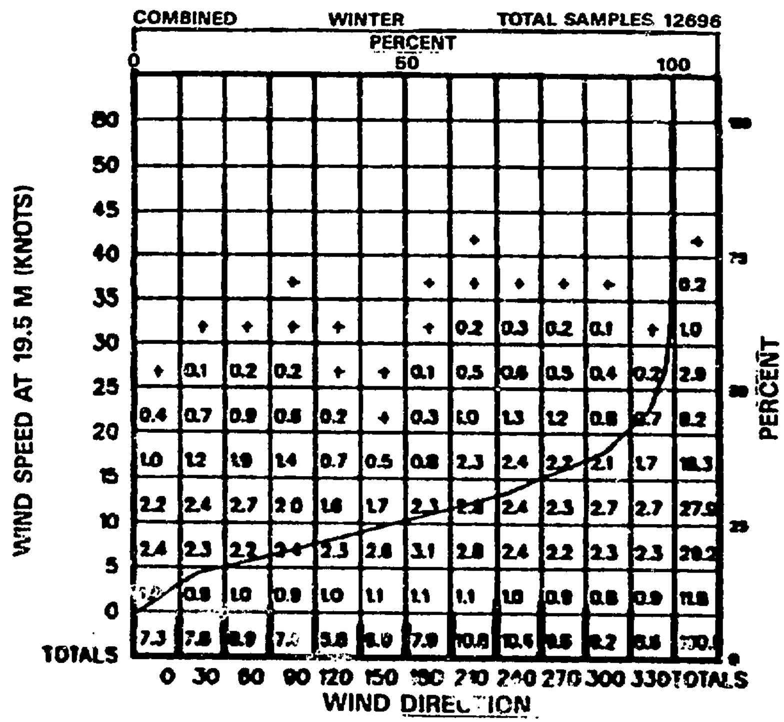


Figure A-COMB-2-4 Wind Speed vs. Wind Direction

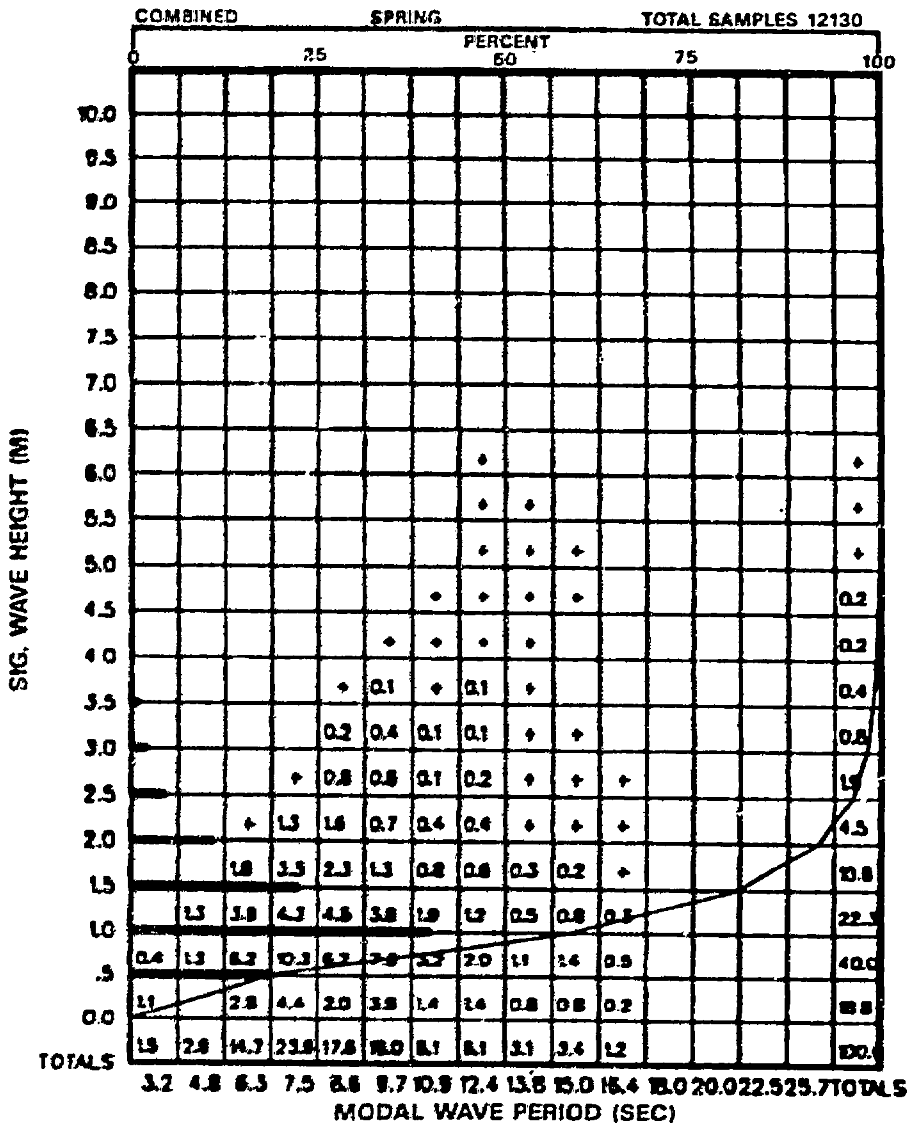


Figure A-COMB-3-1 Significant Wave Height vs. Modal Wave Period

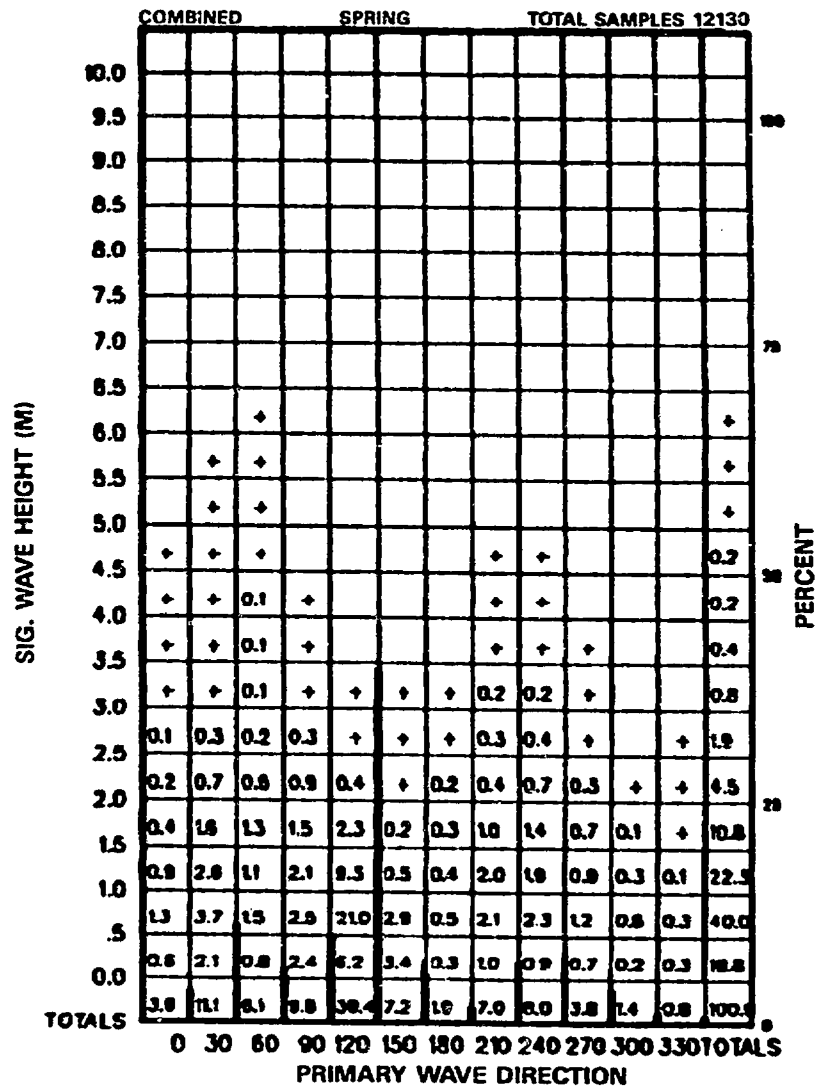


Figure A-COMB-3-2 Significant Wave Height vs. Primary Wave Direction

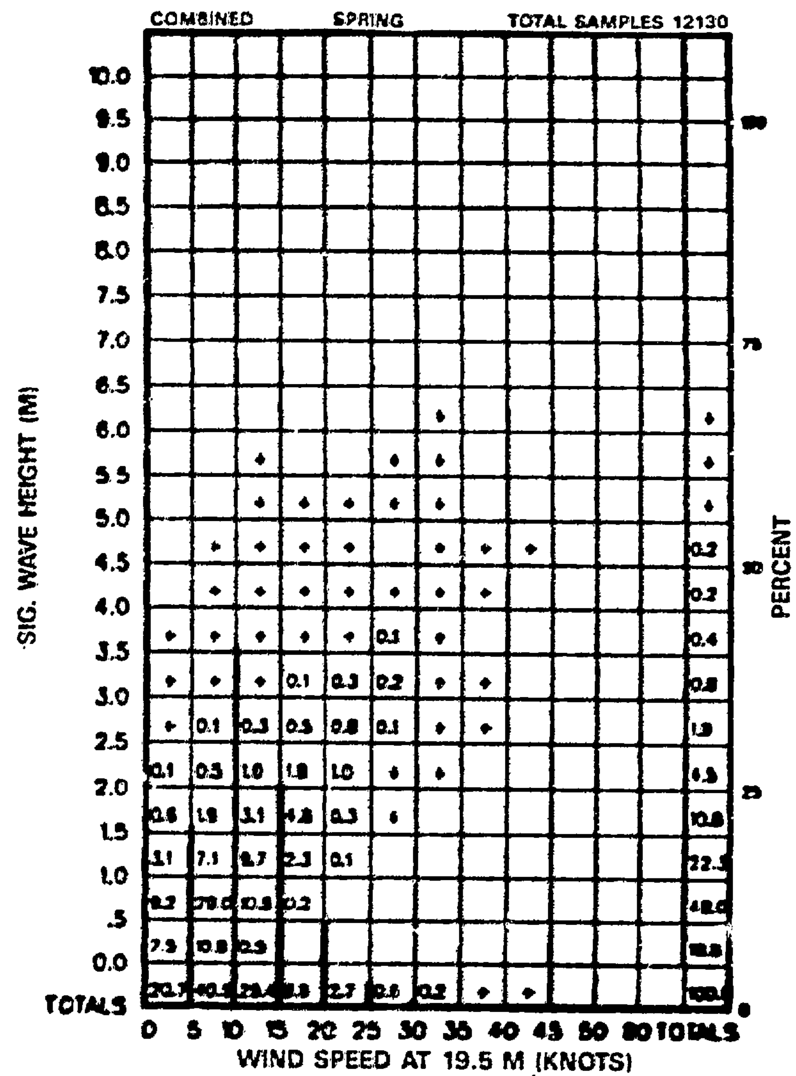


Figure A-COMB-3-3 Significant Wave Height vs. Wind Speed

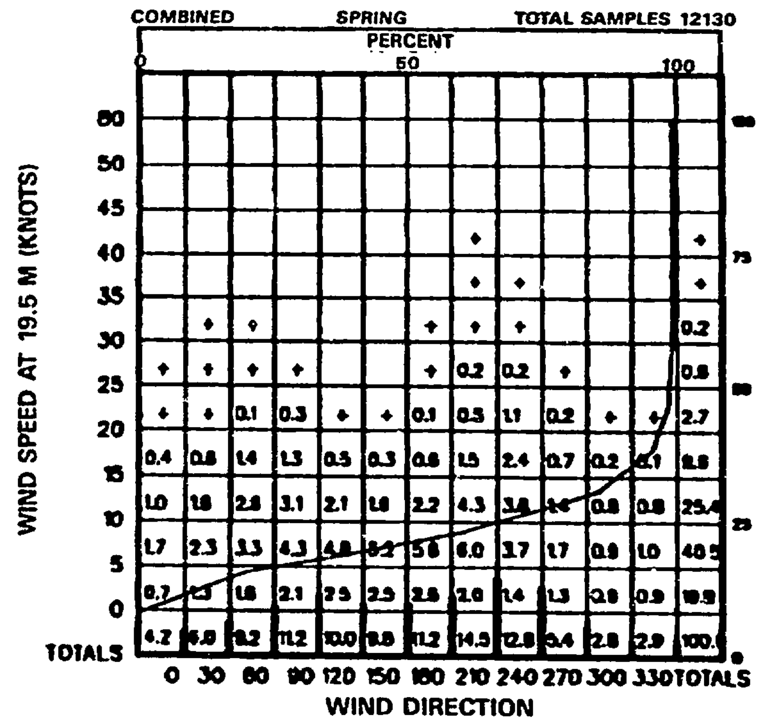


Figure A-COMB-3-4 Wind Speed vs. Wind Direction

COMBINED SUMMER TOTAL SAMPLES 9726

PERCENT 0 25 50 75 100

SIG. WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
10.0																
9.5																
9.0																
8.5																
8.0																
7.5																
7.0																
6.5																
6.0																
5.5																
5.0							+	+	+							+
4.5							+	+								+
4.0						+	+	+								0.1
3.5						0.1	+	+								0.2
3.0					+	0.1	+	+	+							0.3
2.5					0.1	0.3	+	+	+		+					0.5
2.0				0.4	0.4	0.2	0.1	+		+						1.2
1.5			0.7	1.3	0.8	0.7	0.3	0.2	0.1		+					3.9
1.0		0.7	3.1	2.5	3.8	2.7	1.4	0.8	0.2	0.2	+					15.3
.5	0.3	1.0	9.6	12.8	7.0	7.0	2.8	1.2	0.7	1.2	0.1					44.5
0.0	1.5		8.3	8.2	4.0	3.8	1.8	2.2	0.4	0.9	0.2					34.1
TOTALS	1.8	1.8	22.7	23.3	16.1	16.8	5.7	4.8	1.4	2.3	0.4					100.0

MODAL WAVE PERIOD (SEC)

Figure A-COMB-4-1 Significant Wave Height vs.
Modal Wave Period

COMBINED SUMMER TOTAL SAMPLES 9726

SIG. WAVE HEIGHT (M)	0	30	60	90	120	150	180	210	240	270	300	330	TOTALS
10.0													
9.5													
9.0													
8.5													
8.0													
7.5													
7.0													
6.5													
6.0													
5.5													
5.0				+									+
4.5			+	+									+
4.0			+	+									0.1
3.5			0.1	+									0.2
3.0	+	+	0.1	+	+			+	+				0.3
2.5	+	+	0.1	+	+	+	+	+	+			+	0.5
2.0	+	0.2	0.1	0.2	0.1	+	+	0.2	0.2	+		+	1.2
1.5	+	0.4	0.2	0.5	1.3	0.1	+	0.8	0.6	+			3.9
1.0	0.1	0.7	0.5	1.3	8.4	0.5	0.2	2.0	1.3	0.3			15.3
.5	0.5	1.2	0.3	3.4	31.0	2.8	0.3	2.4	2.0	0.6	+		44.5
0.0	0.3	1.1	0.2	5.5	17.5	5.8	0.5	1.3	1.3	0.4	0.1	+	34.1
TOTALS	1.1	3.7	1.9	11.2	58.5	9.0	1.1	6.7	5.4	1.3	0.2	+	100.0

PRIMARY WAVE DIRECTION

PERCENT

Figure A-COMB-4-2 Significant Wave Height vs.
Primary Wave Direction

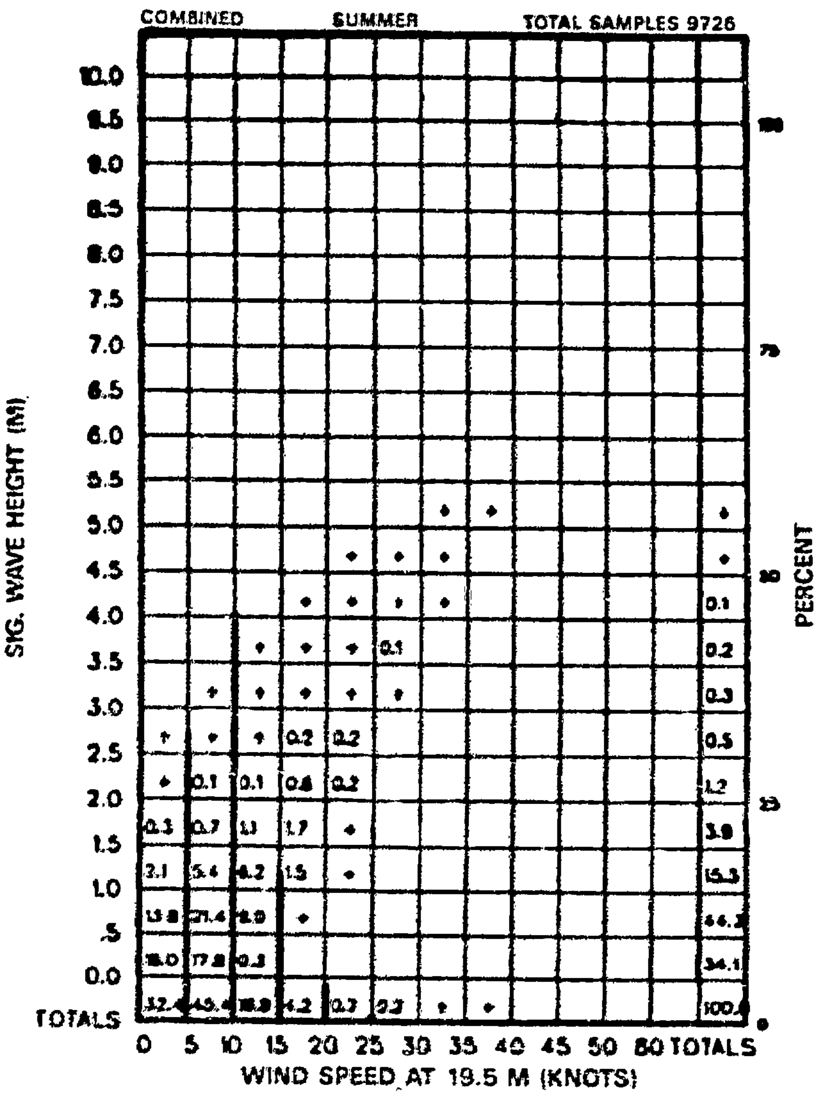


Figure A-COMB-4-3 Significant Wave Height vs. Wind Speed

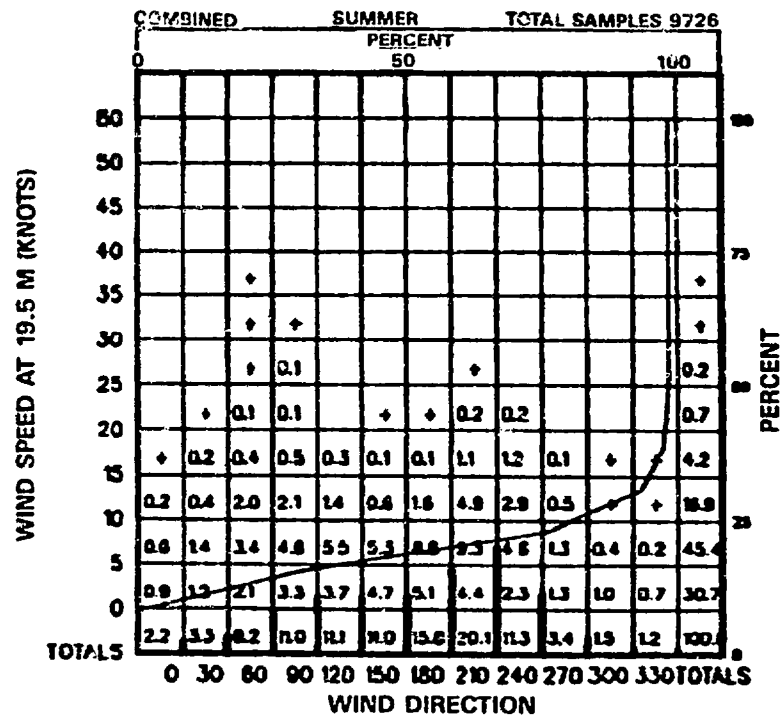


Figure A-COMB-4-4 Wind Speed vs. Wind Direction

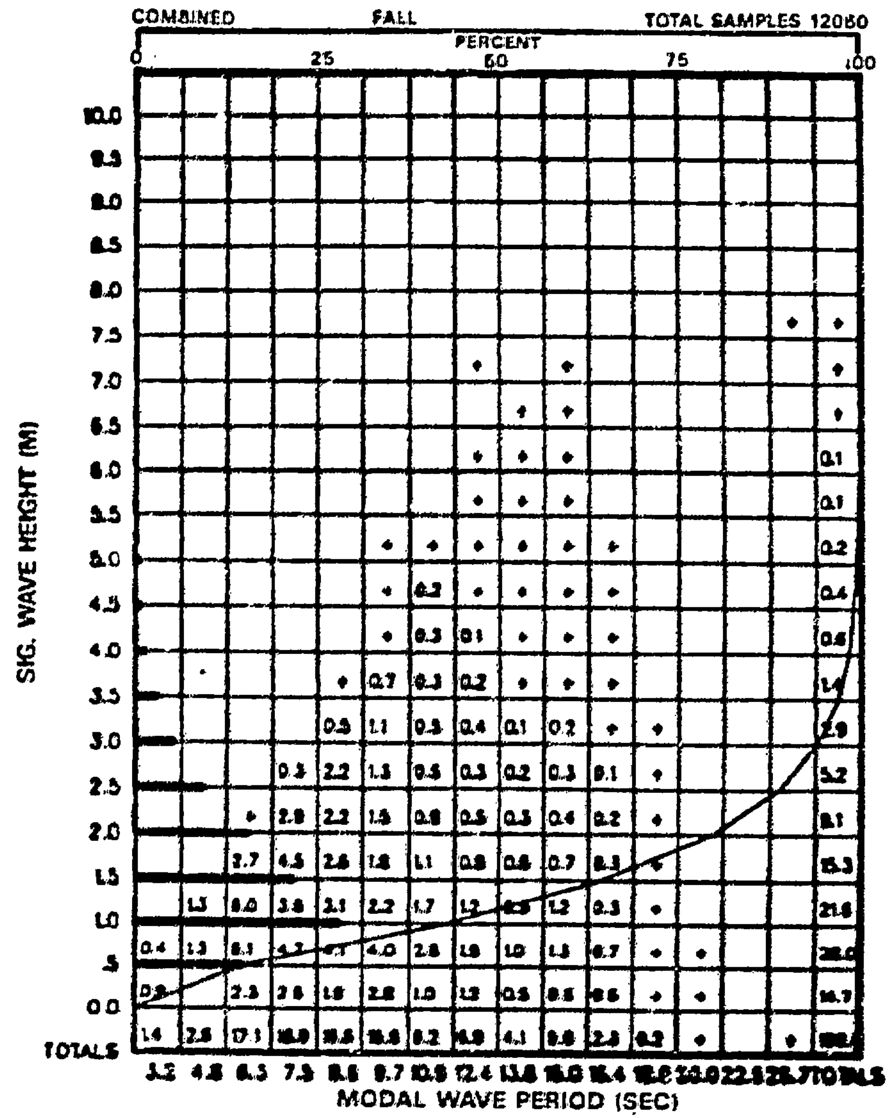


Figure A-COMB-5-1 Significant Wave Height vs. Modal Wave Period

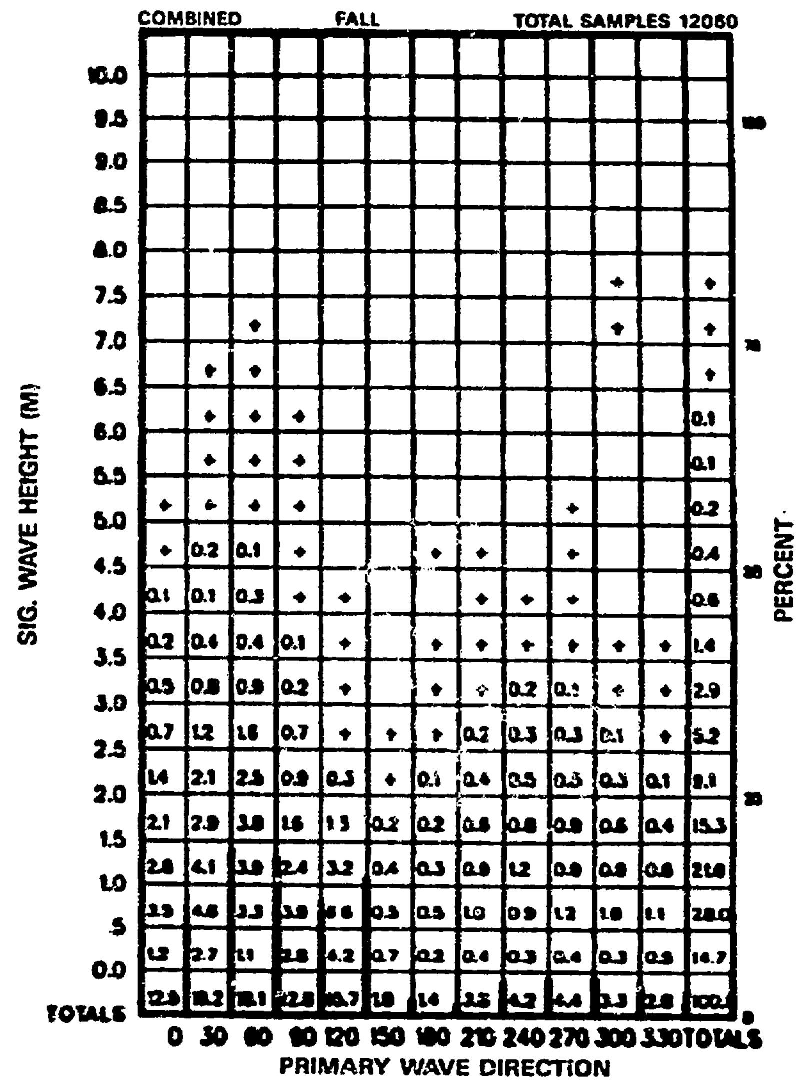


Figure A-COMB-5-2 Significant Wave Height vs. Primary Wave Direction

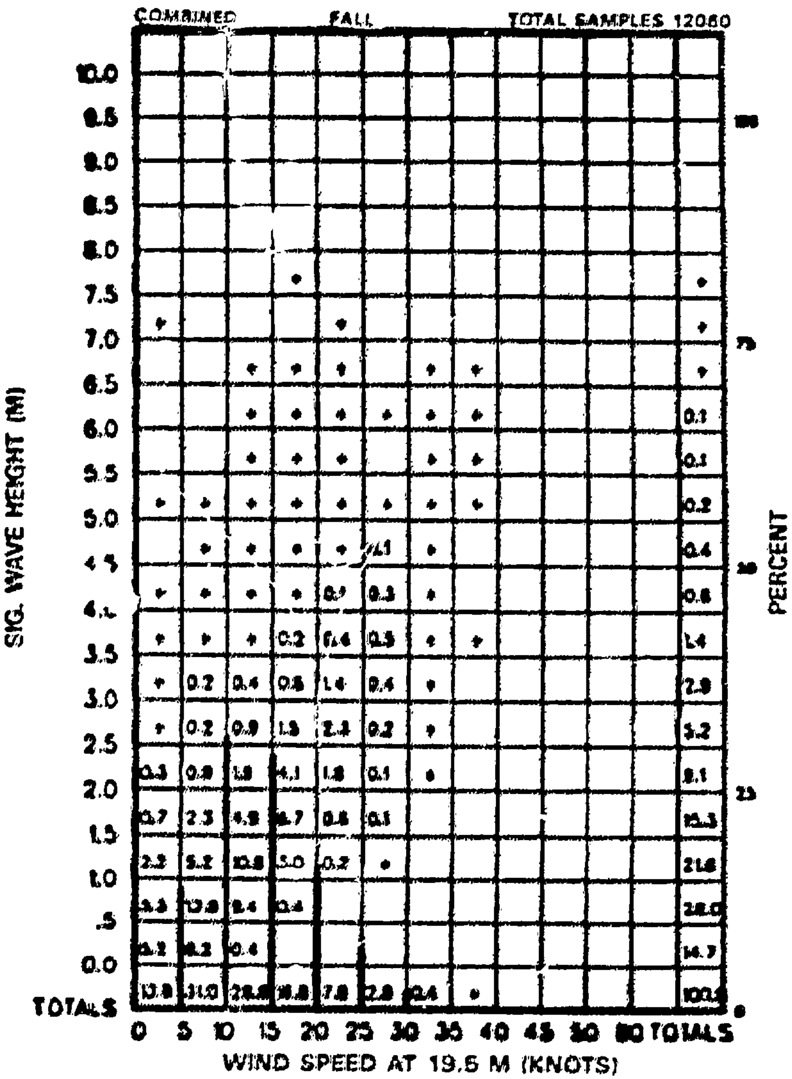


Figure A-COMB-5-3 Significant Wave Height vs. Wind Speed

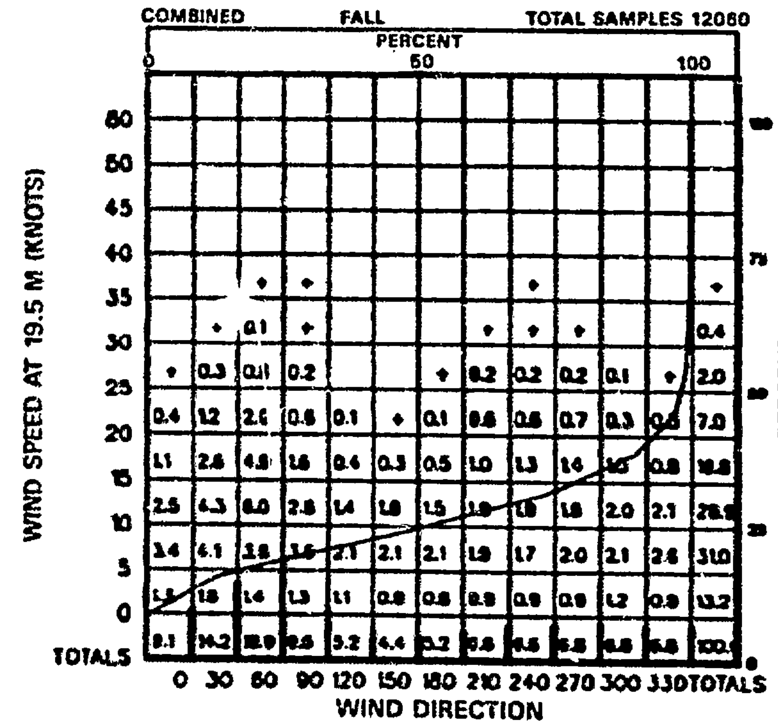


Figure A-COMB-5-4 Wind Speed vs. Wind Direction

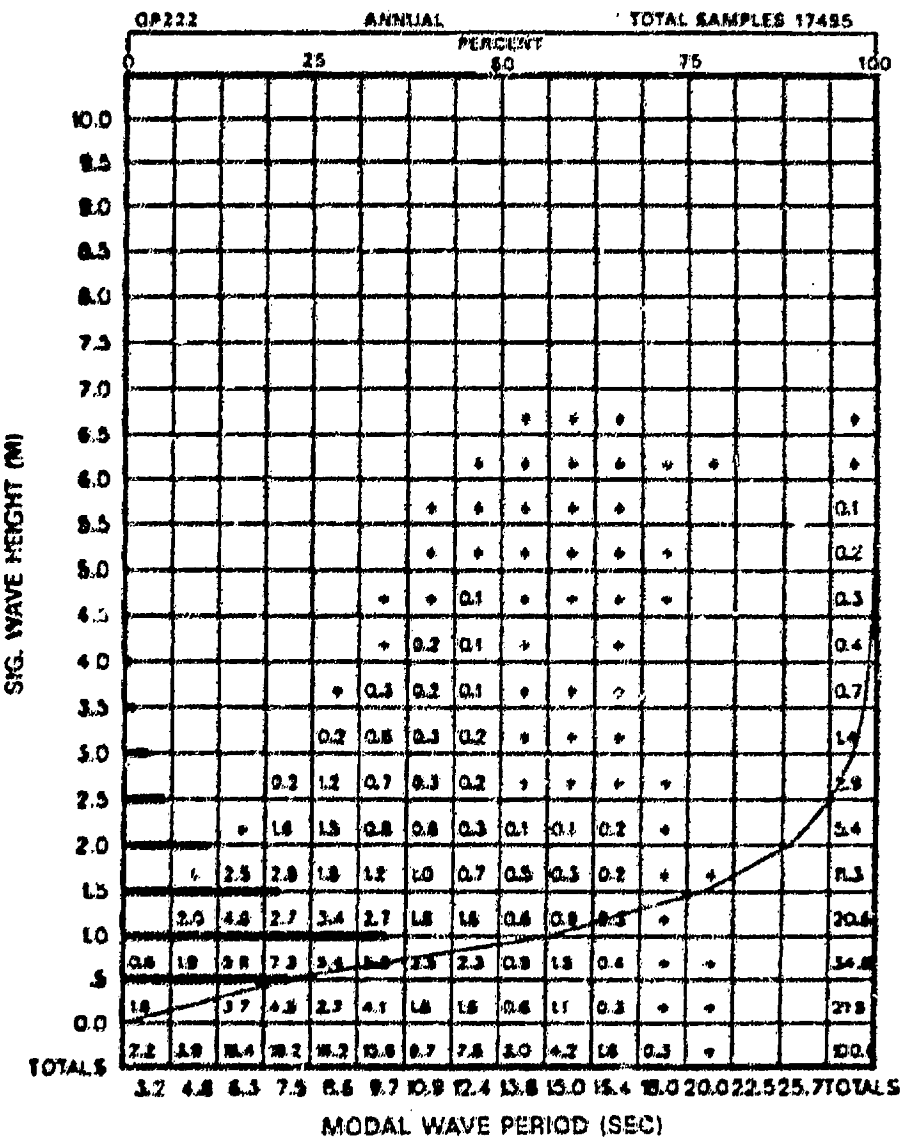


Figure A-222-1-1 Significant Wave Height vs. Modal Wave Period

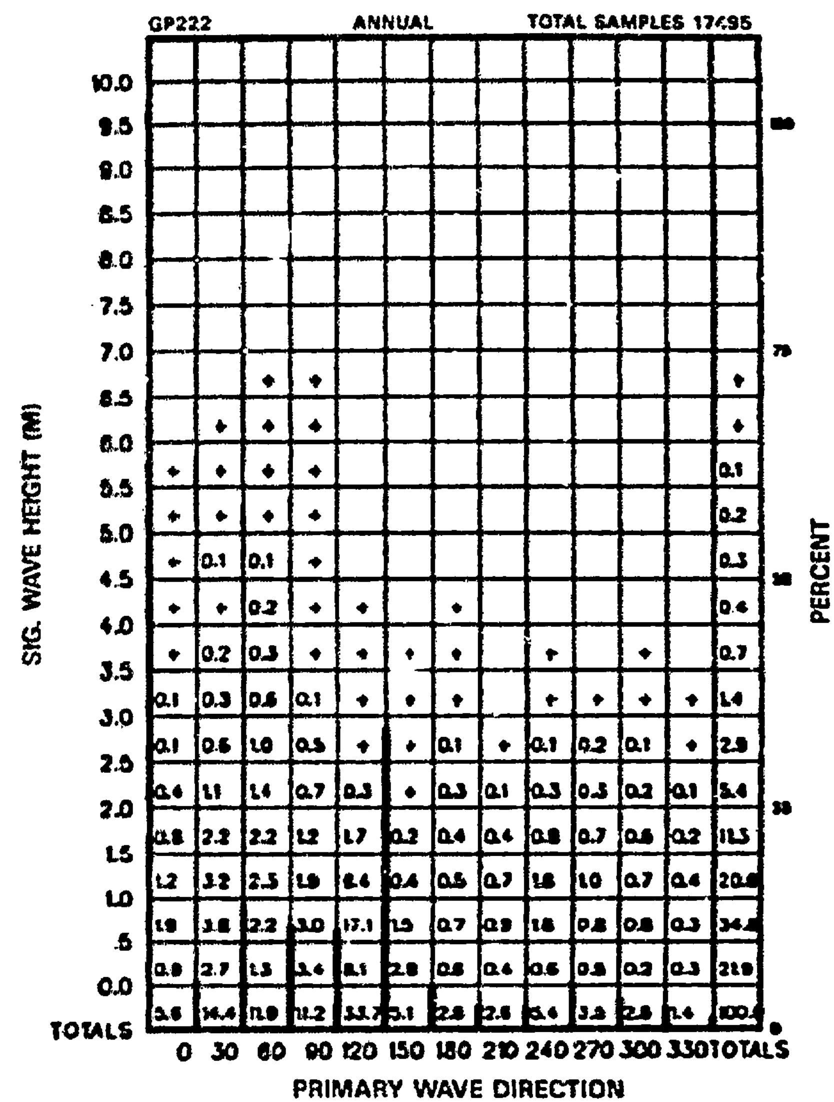


Figure A-222-1-2 Significant Wave Height vs. Primary Wave Direction

SIG. WAVE HEIGHT (M)	0	5	10	15	20	25	30	35	40	45	50	80	TOTALS
10.0													
9.5													
9.0													
8.5													
8.0													
7.5													
7.0													
6.5		+	+					+					+
6.0	+	+	+	+		+	+	+					+
5.5	+		+	+		+	+	+					0.1
5.0	+		+	+	+	+	+	+					0.2
4.5	+	+	+	+	+	+	+						0.3
4.0	+	+	+	+	+	0.1	+	+					0.4
3.5	+	+	+	0.1	0.2	0.2	+						0.7
3.0	+	+	0.1	0.3	0.8	0.3	+						1.4
2.5	+	0.1	0.5	0.7	1.2	0.2	+	+					2.9
2.0	0.1	0.4	0.8	2.3	1.5	0.2	+	+					5.4
1.5	0.4	1.4	2.8	5.4	0.8	0.2	+						11.3
1.0	2.0	5.4	8.0	3.8	0.4	+							20.8
.5	8.4	14.8	11.1	0.6									34.8
0.0	8.7	12.7	0.5										21.9
TOTALS	18.8	35.1	20.1	13.3	4.8	1.4	0.4	+					100.0

GP222 ANNUAL TOTAL SAMPLES 17495

WIND SPEED AT 19.5 M (KNOTS)

PERCENT 25 50 75 100

Figure A-222-1-3 Significant Wave Height vs. Wind Speed

WIND SPEED AT 19.5 M (KNOTS)	0	30	60	90	120	150	180	210	240	270	300	330	TOTALS
80													
50													
45													
40													
35			+	+				+	+				+
30		+	0.1	+				+	+	+	+	+	0.4
25	+	0.2	0.3	0.1	+	+	+	0.1	0.2	0.2	0.2	+	1.4
20	0.2	0.8	1.0	0.5	+	+	0.1	0.5	0.8	0.6	0.4	0.3	4.8
15	0.7	1.4	2.7	1.4	0.6	0.3	0.4	1.0	1.7	1.2	1.1	0.8	13.3
10	1.6	2.3	3.7	2.7	1.6	1.1	1.6	2.7	3.0	1.5	1.5	1.5	25.1
5	2.1	2.7	3.4	3.7	3.3	3.5	[illegible]	4.7	3.0	1.8	1.3	1.8	35.1
0	1.0	1.3	1.5	2.0	2.2	2.2	2.4	2.3	1.3	1.0	0.8	0.8	18.0
TOTALS	6.0	8.7	12.8	10.8	7.8	7.2	8.7	11.4	10.0	6.3	5.3	5.2	100.0

GP222 ANNUAL TOTAL SAMPLES 17495

PERCENT 0 50 100

WIND DIRECTION

PERCENT 25 50 75 100

Figure A-222-1-4 Wind Speed vs. Wind Direction

GP222 ANNUAL TOTAL SAMPLES 17495

SIG. WAVE HEIGHT (M)	0	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	TOTALS
10.0																						
9.5																						
9.0																						
8.5																						
8.0																						
7.5																						
7.0																						
6.5	4																					4
6.0	5	2	1																			8
5.5	8	3	7																			13
5.0	15	6	2																			22
4.5	25	6	3	1																		35
4.0	24	13	3	1																		41
3.5	48	24	3	1		1	1															78
3.0	72	38	14	8	2	1																136
2.5	148	88	28	17	2	5	1	3														274
2.0	252	118	46	30	15	7	3	3	3													478
1.5	424	248	104	50	30	15	10	9	4	3	2		1	2		2						904
1.0	817	314	334	137	66	54	19	20	7	7	3	4	3	1	1	2	1		2	2	1	1414
.5	843	330	219	155	103	82	56	36	28	19	16	15	10	13	6	5	10	4	1	7	12	1788
0.0	374	212	156	100	57	50	37	31	18	8	6	8	8	4	5	5	5		5	1	7	1095
TOTALS	2661	1413	786	471	274	168	127	102	59	37	28	27	20	17	12	14	18	4	8	10	20	6271

DURATION (HOURS)

PERCENT: 100, 75, 50, 25, 0

Figure A-222-1-5 Persistence of Wave Height

GP222 ANNUAL TOTAL SAMPLES 17495

WIND SPEED AT 19.5 M (KNOTS)	0	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	TOTALS
50–60																						
45–50																						
40–45																						
35–40	5	5																				10
30–35	26	16	6																			48
25–30	106	41	11	2	2						1											163
20–25	283	125	53	18	6	2	1	2	2													492
15–20	582	272	119	80	43	13	17	8	1		2											1139
10–15	909	424	275	141	83	48	28	12	9	6	1	6	1	1								1944
5–10	804	504	333	182	90	68	38	33	20	18	14	8	6	5	5	1		2	2	1	3	225[illegible]
0–5	438	208	130	81	45	55	28	25	18	8	9	8	7	4	6	2	1	2		1	7	1065
TOTALS	[illegible]	[illegible]	927	514	278	156	114	80	48	33	27	23	14	10	11	3	1	4	2	2	10	7135

DURATION (HOURS)

PERCENT: 100, 75, 50, 25, 0

Figure A-222-1-5 Persistence of Wind Speed

GP222 WINTER TOTAL SAMPLES 4157

PERCENT: 0, 25, 50, 75, 100

SIG. WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
9.5–10.0																
9.0–9.5																
8.5–9.0																
8.0–8.5																
7.5–8.0																
7.0–7.5																
6.5–7.0									+		+					+
6.0–6.5											+	+	+			0.1
5.5–6.0								+	+		+					0.2
5.0–5.5							+	+	+		+	+				0.2
4.5–5.0							+	0.2	+		0.1	+				0.5
4.0–4.5						+	0.2	0.2	+		+					0.5
3.5–4.0					+	0.4	0.4	0.1	0.1	0.1	+					1.2
3.0–3.5					0.4	0.8	0.8	0.2	+	0.1	+					2.2
2.5–3.0				0.4	1.9	0.7	0.6	0.5	0.1	0.2	0.1	+				4.5
2.0–2.5			+	2.7	2.3	1.0	0.8	0.9	0.3	0.2	0.4	0.2				8.9
1.5–2.0		+	3.8	4.1	1.8	1.6	1.5	1.5	0.6	0.7	0.6	0.2	+			15.4
1.0–1.5		2.6	4.8	2.5	2.8	2.8	2.4	2.9	0.7	1.6	0.4	0.1				23.5
0.5–1.0	0.6	1.7	3.7	3.4	3.2	4.6	3.8	3.2	1.1	2.7	0.8	0.3	+			28.6
0.0–0.5	1.0		1.3	1.4	1.4	2.9	1.6	1.4	0.6	1.5	0.5	+				13.3
TOTALS	1.6	4.1	13.8	14.6	13.7	14.0	12.6	11.1	3.6	7.2	3.3	1.1	+			100.0

MODAL WAVE PERIOD (SEC)

Figure A-222-2-1 Significant Wave Height vs. Modal Wave Period

GP222 WINTER TOTAL SAMPLES 4157

SIG. WAVE HEIGHT (M)	0	30	60	90	120	150	180	210	240	270	300	330	TOTALS
9.5–10.0													
9.0–9.5													
8.5–9.0													
8.0–8.5													
7.5–8.0													
7.0–7.5													
6.5–7.0			+	+									+
6.0–6.5		+	+										0.1
5.5–6.0	+	+	+	+									0.2
5.0–5.5	+	+	+	+									0.2
4.5–5.0	+	0.3	0.1	+									0.5
4.0–4.5		0.1	0.2	+			+						0.5
3.5–4.0	+	0.4	0.4	0.2	+		+		+		+		1.2
3.0–3.5	0.3	0.4	0.7	0.1	+		+		0.2	0.1	0.1	+	2.2
2.5–3.0	0.3	1.1	1.1	0.4	0.1	+	0.2	0.1	0.3	0.4	0.3	+	4.5
2.0–2.5	1.1	2.2	1.6	0.5	0.5	0.2	0.5	0.3	0.6	0.6	0.5	0.4	8.9
1.5–2.0	1.6	3.5	2.3	0.8	1.7	0.3	0.5	0.8	1.5	1.3	1.4	0.6	15.4
1.0–1.5	2.2	5.4	1.5	1.1	5.1	0.8	0.6	0.7	1.8	1.8	1.5	0.9	23.5
0.5–1.0	3.7	8.0	2.2	1.8	8.2	1.2	1.2	0.7	0.7	0.9	1.5	0.5	28.6
0.0–0.5	1.3	3.1	1.1	1.8	3.1	0.9	0.6	+	0.3	0.3	0.2	0.4	13.3
TOTALS	10.6	22.7	11.6	6.9	18.8	3.2	3.8	2.7	5.5	5.4	5.7	3.0	100.0

PRIMARY WAVE DIRECTION

PERCENT

Figure A-222-2-2 Significant Wave Height vs. Primary Wave Direction

GP222 WINTER TOTAL SAMPLES 4157

SIG. WAVE HEIGHT (M) \ WIND SPEED AT 19.5 M (KNOTS)	0	5	10	15	20	25	30	35	40	45	50	60	TOTALS
10.0													
9.5													
9.0													
8.5													
8.0													
7.5													
7.0													
6.5		+						+					+
6.0	+	+		+									0.1
5.5	+		+			+	+	+					0.2
5.0	+		+	+	+		+						0.2
4.5	+	+	+	0.2		0.1	+						0.5
4.0	+	+	+	+	+	+	+	+					0.5
3.5	+	+	+	0.2	0.3	0.4	+						1.2
3.0	+	0.2	+	0.2	0.9	0.6	0.2						2.2
2.5	0.3	0.3	0.5	0.8	1.9	0.6	0.2	+					4.5
2.0	0.2	0.5	1.3	3.3	2.6	0.6	0.2	+					8.9
1.5	0.5	1.6	3.8	8.2	1.8	0.3	+						16.4
1.0	1.7	5.3	10.0	5.4	0.8	0.1							23.3
.5	4.2	11.9	7.7	0.5									28.6
0.0	4.1	8.9	0.4										13.3
TOTALS	11.2	29.0	28.0	19.3	8.3	2.9	1.0	0.1					100.0

Figure A-222-2-3 Significant Wave Height vs. Wind Speed

GP222 WINTER TOTAL SAMPLES 4157

WIND SPEED AT 19.5 M (KNOTS) \ WIND DIRECTION	0	30	60	90	120	150	180	210	240	270	300	330	TOTALS
60													
50													
45													
40													
35				+				+	+				0.1
30		+		0.1				0.1	0.2	0.2	0.2	+	1.0
25	0.1	0.2	0.3	0.2			0.1	0.3	0.6	0.5	0.4	0.2	2.9
20	0.3	0.8	1.2	0.7	0.1	+	0.3	0.8	1.1	1.2	1.0	0.9	8.5
15	1.1	1.6	2.1	1.5	0.7	0.5	0.7	2.0	2.3	2.3	2.5	2.1	19.3
10	2.9	2.4	2.7	2.2	1.5	1.6	2.3	2.3	2.3	2.0	2.9	2.9	28.0
5	2.7	2.4	2.1	2.5	1.8	3.0	2.9	2.5	2.5	1.8	2.1	2.7	28.0
0	0.9	0.6	0.8	0.6	0.8	0.8	1.1	1.3	1.1	0.9	0.6	0.9	10.6
TOTALS	8.2	8.1	8.3	7.9	5.0	6.2	7.3	9.4	10.1	9.0	9.5	9.6	100.0

Figure A-222-2-4 Wind Speed vs. Wind Direction

GP222 SPRING TOTAL SAMPLES 4102

PERCENT 0 25 50 75 100

SIG. WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
9.5–10.0																
9.0–9.5																
8.5–9.0																
8.0–8.5																
7.5–8.0																
7.0–7.5																
6.5–7.0																
6.0–6.5																
5.5–6.0								+								+
5.0–5.5								+								+
4.5–5.0								+	+	+						0.1
4.0–4.5						+		+	0.1							0.2
3.5–4.0						+		+	+							0.1
3.0–3.5					+	0.1	+	+	+							0.4
2.5–3.0				+	0.5	0.5	0.1	0.1	+							1.3
2.0–2.5				0.8	1.3	0.8	0.2	0.1	+	+	+					3.1
1.5–2.0			1.8	2.3	2.7	1.2	0.8	0.3	0.3	0.3	+					10.0
1.0–1.5		2.1	4.0	3.3	4.8	3.5	1.9	1.6	0.9	0.8	0.2					22.5
0.5–1.0	0.6	2.5	3.5	10.6	6.5	6.7	2.9	2.2	1.0	0.8	0.4					41.1
0.0–0.5	1.8		2.7	5.1	2.2	4.6	1.5	1.7	0.4	1.1	0.3					21.0
TOTALS	2.2	4.7	14.0	22.1	18.3	17.3	8.5	8.3	2.6	3.1	1.0					100.0

MODAL WAVE PERIOD (SEC)

Figure A-222-3-1 Significant Wave Height vs. Modal Wave Period

GP222 SPRING TOTAL SAMPLES 4102

SIG. WAVE HEIGHT (M)	0	30	60	90	120	150	180	210	240	270	300	330	TOTALS
9.5–10.0													
9.0–9.5													
8.5–9.0													
8.0–8.5													
7.5–8.0													
7.0–7.5													
6.5–7.0													
6.0–6.5													
5.5–6.0		+	+										+
5.0–5.5		+	+										+
4.5–5.0		+	0.1										0.1
4.0–4.5			0.2	+									0.2
3.5–4.0		+	+	+									0.1
3.0–3.5		+	0.1	+	+				+				0.4
2.5–3.0	+	+	0.2	0.4	0.1	+	0.1	+	0.1	+			1.3
2.0–2.5		0.3	0.8	0.8	0.2	0.1	0.3	0.1	0.3	+	+	+	3.1
1.5–2.0	0.1	1.5	1.7	1.6	2.4	0.1	0.5	0.5	0.9	0.6	+	+	10.0
1.0–1.5	0.5	2.4	1.5	2.7	9.8	0.2	0.7	1.0	2.6	0.9	0.3	0.1	22.5
0.5–1.0	0.8	3.7	1.6	2.8	23.1	2.3	0.9	1.0	2.9	1.0	0.7	0.3	41.1
0.0–0.5	0.8	2.2	1.2	2.8	8.9	4.4	0.4	0.6	0.7	0.8	0.1	0.2	21.0
TOTALS	2.2	10.4	7.4	10.8	42.8	7.2	2.9	3.3	7.7	3.4	1.3	0.7	100.0

PRIMARY WAVE DIRECTION

PERCENT

Figure A-222-3-2 Significant Wave Height vs. Primary Wave Direction

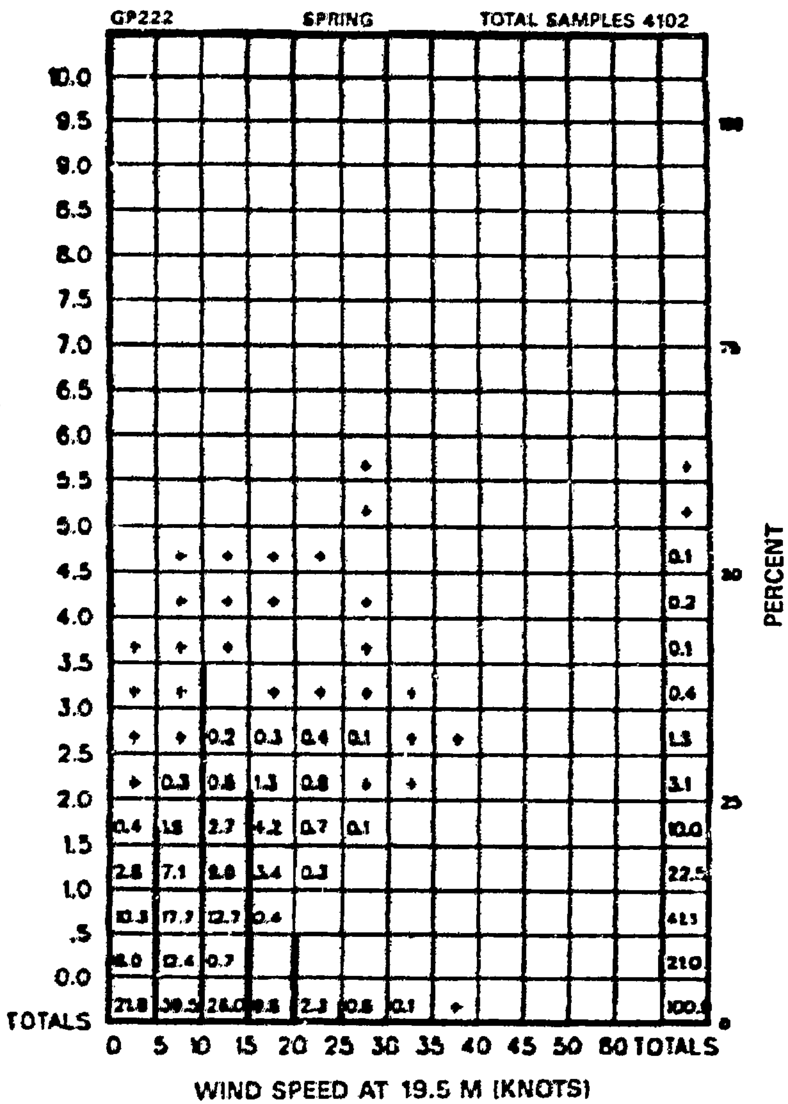


Figure A-222-3-3 Significant Wave Height vs. Wind Speed

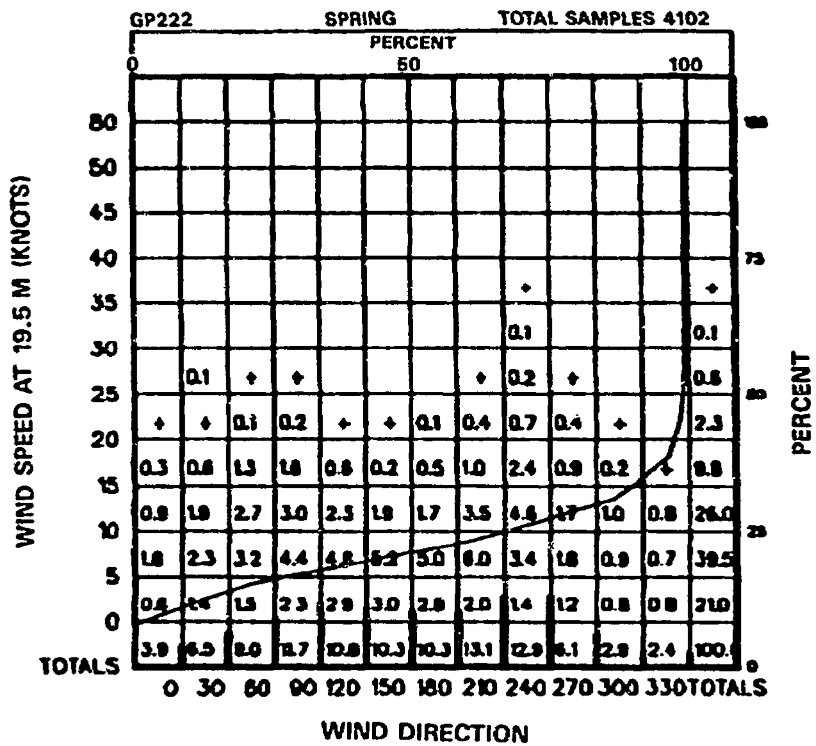


Figure A-222-3-4 Wind Speed vs. Wind Direction

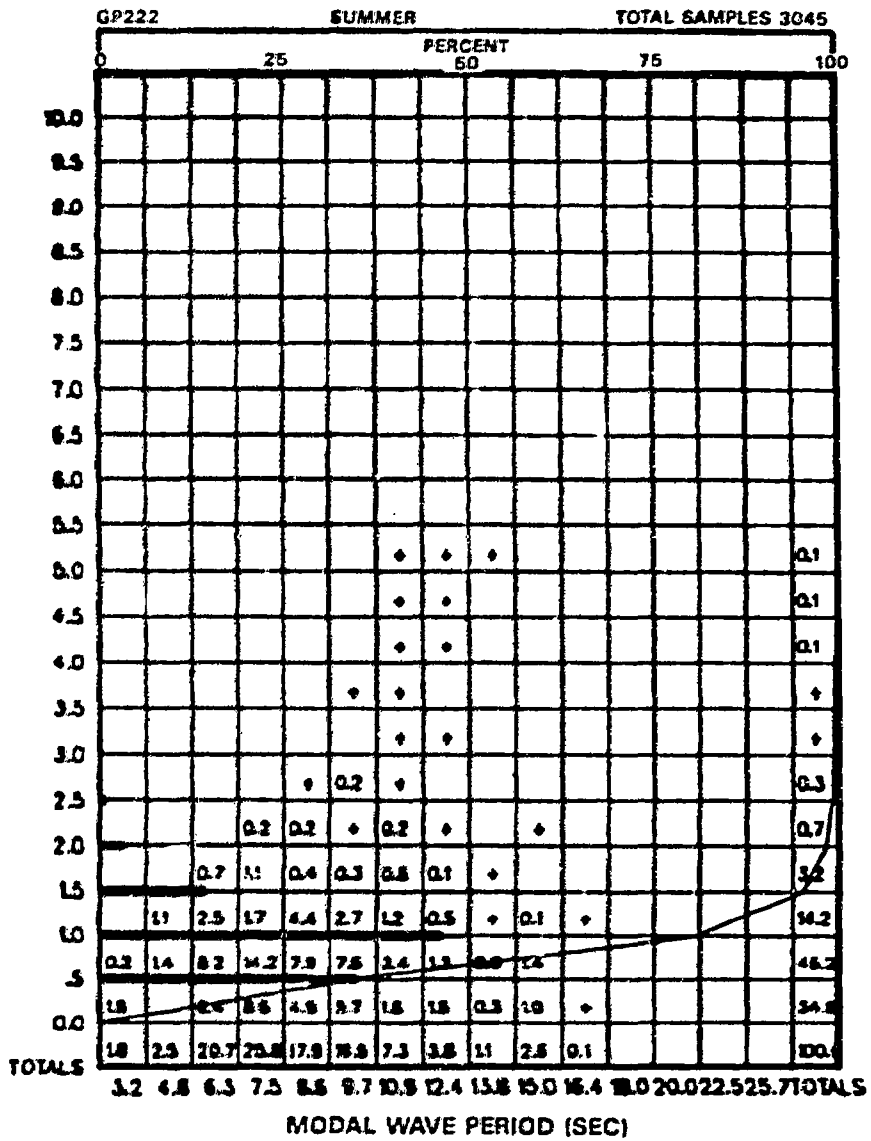


Figure A-222-4-1 Significant Wave Height vs. Modal Wave Period

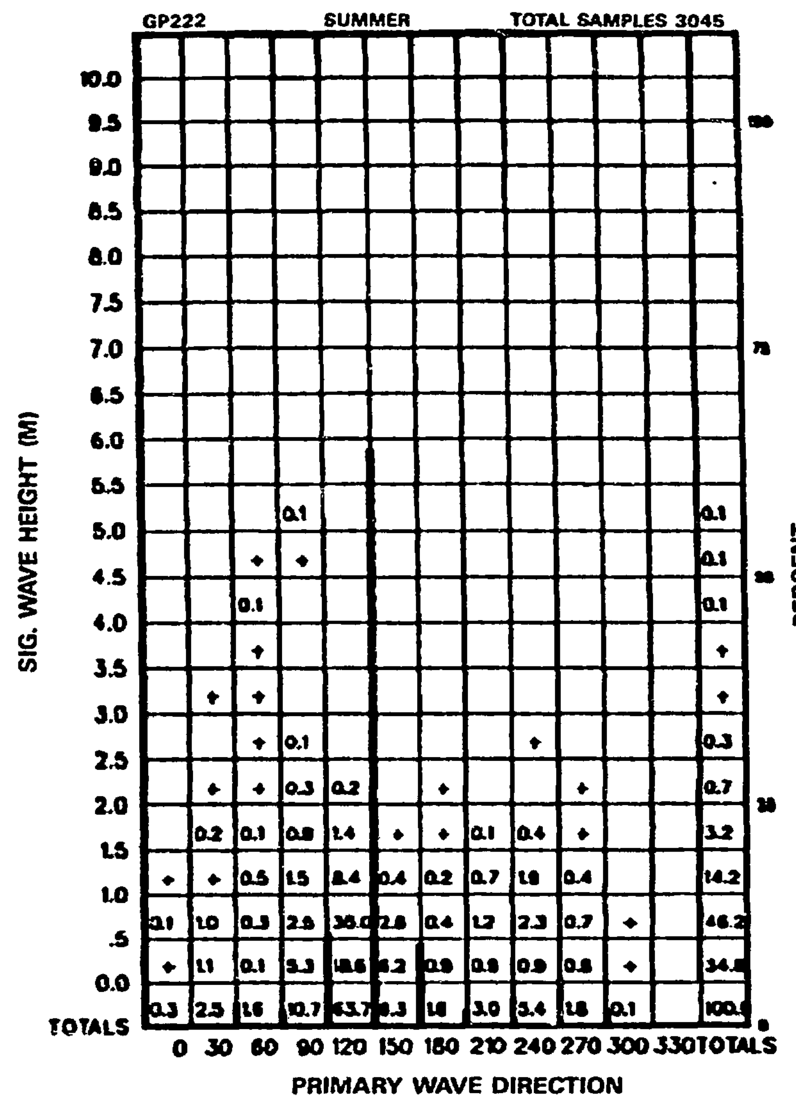


Figure A-222-4-2 Significant Wave Height vs. Primary Wave Direction

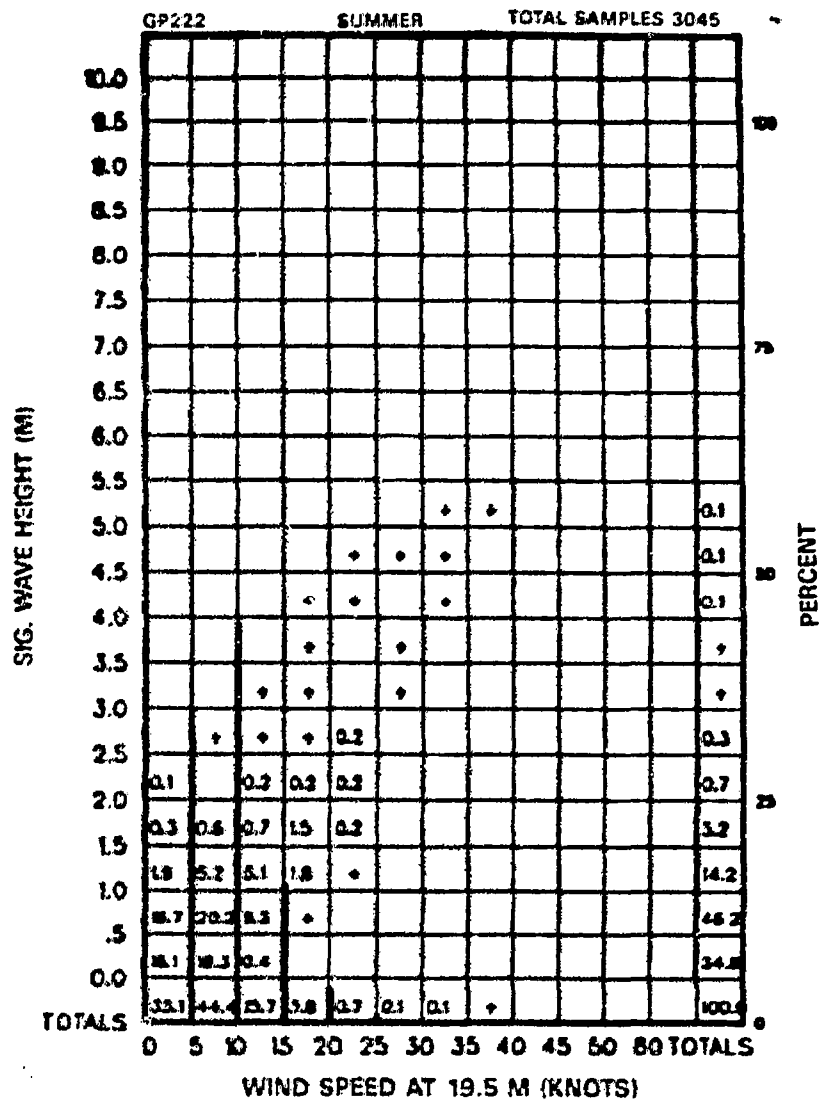


Figure A-222-4-3 Significant Wave Height vs. Wind Speed

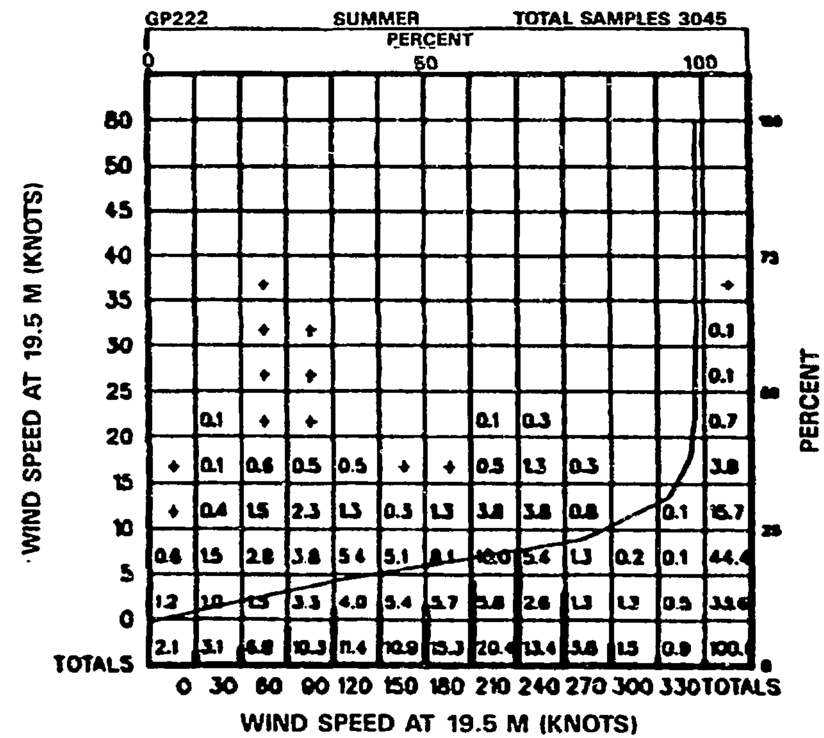


Figure A-222-4-4 Wind Speed vs. Wind Direction

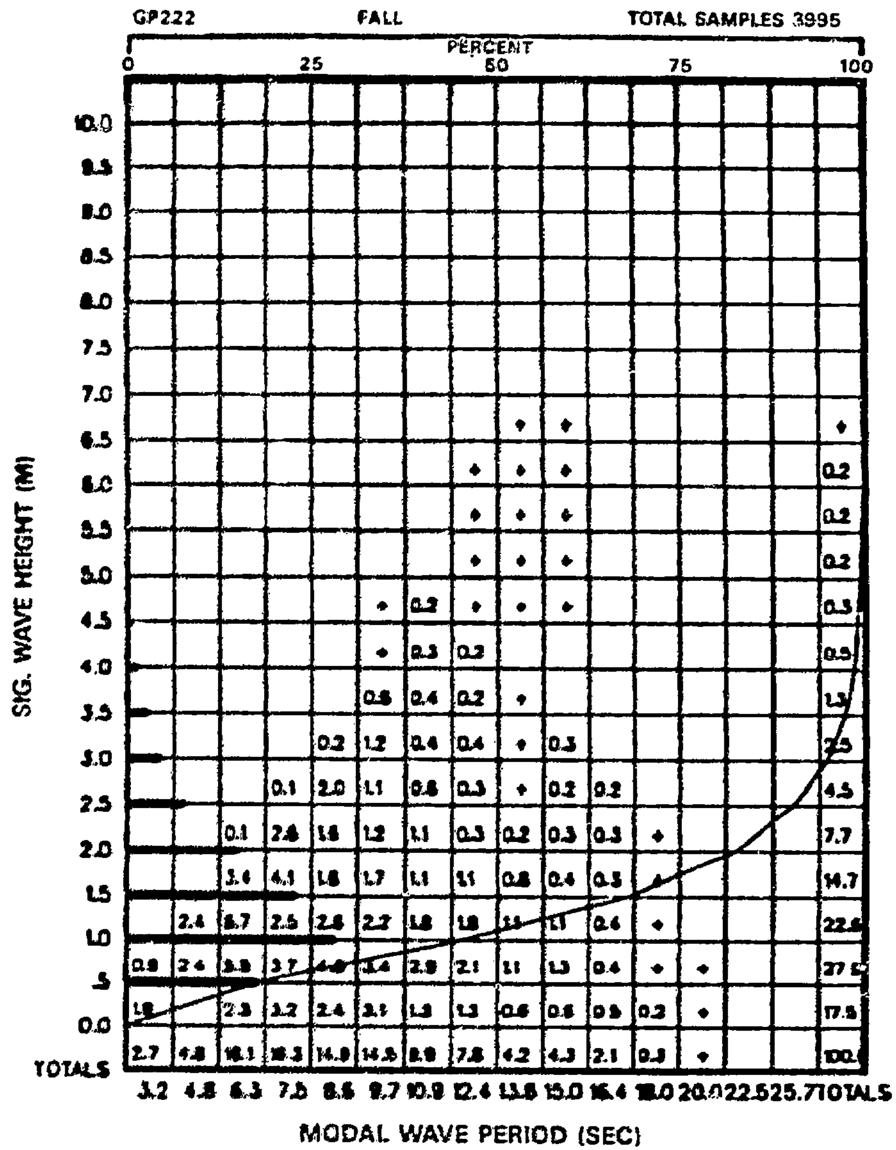


Figure A-222-5-1 Significant Wave Height vs. Modal Wave Period

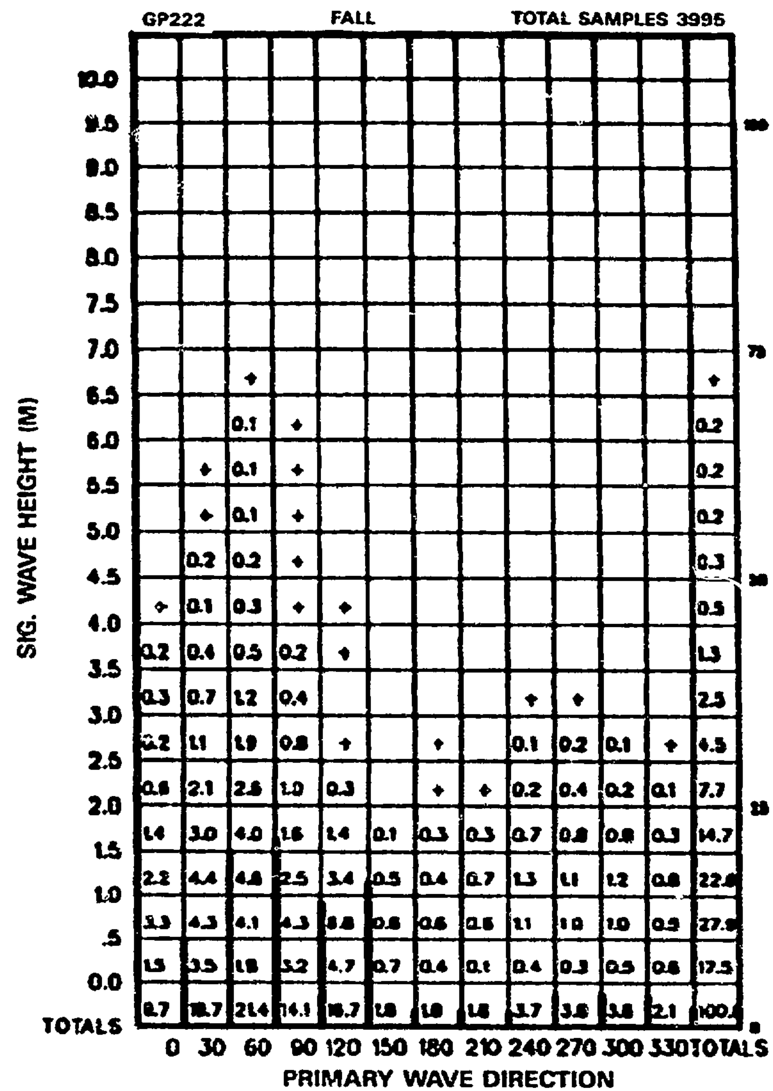


Figure A-222-5-2 Significant Wave Height vs. Primary Wave Direction

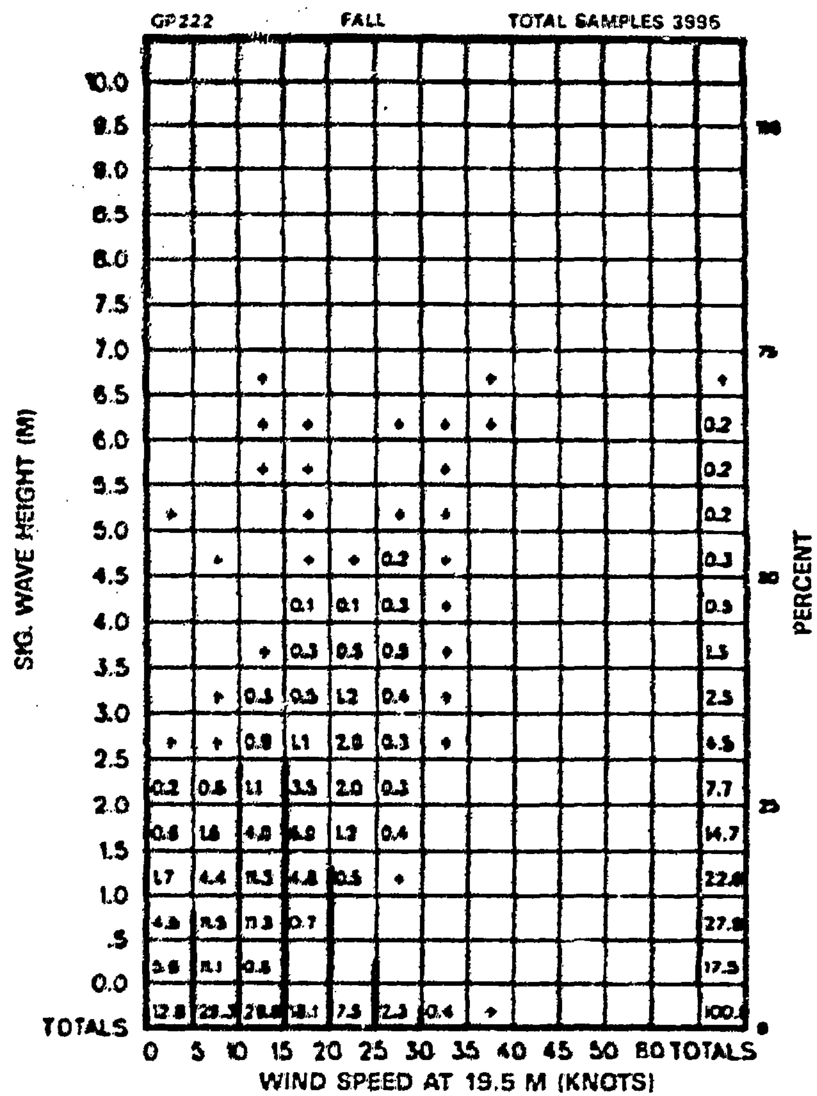


Figure A-222-5-3 Significant Wave Height vs. Wind Speed

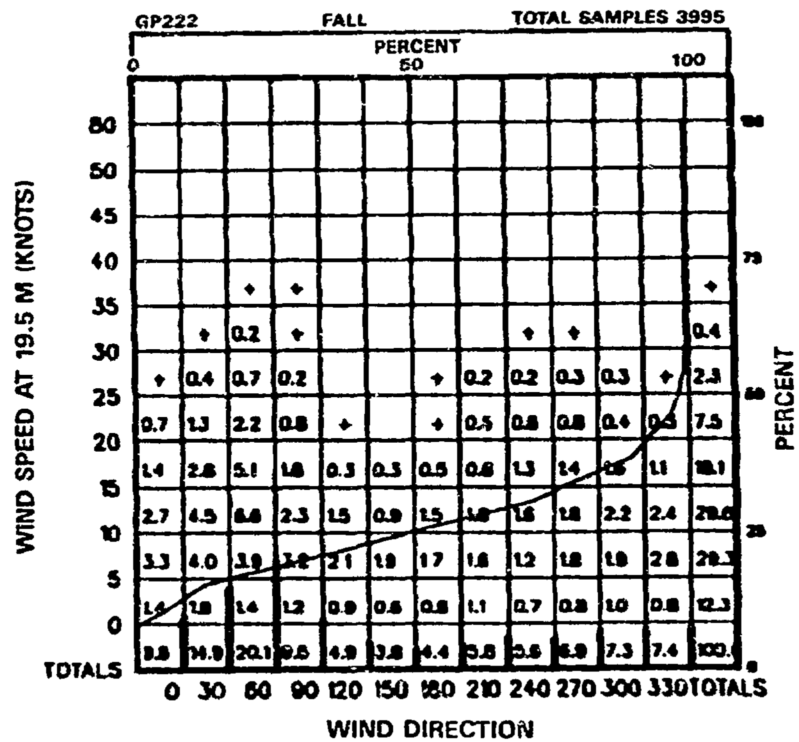


Figure A-222-5-4 Wind Speed vs. Wind Direction

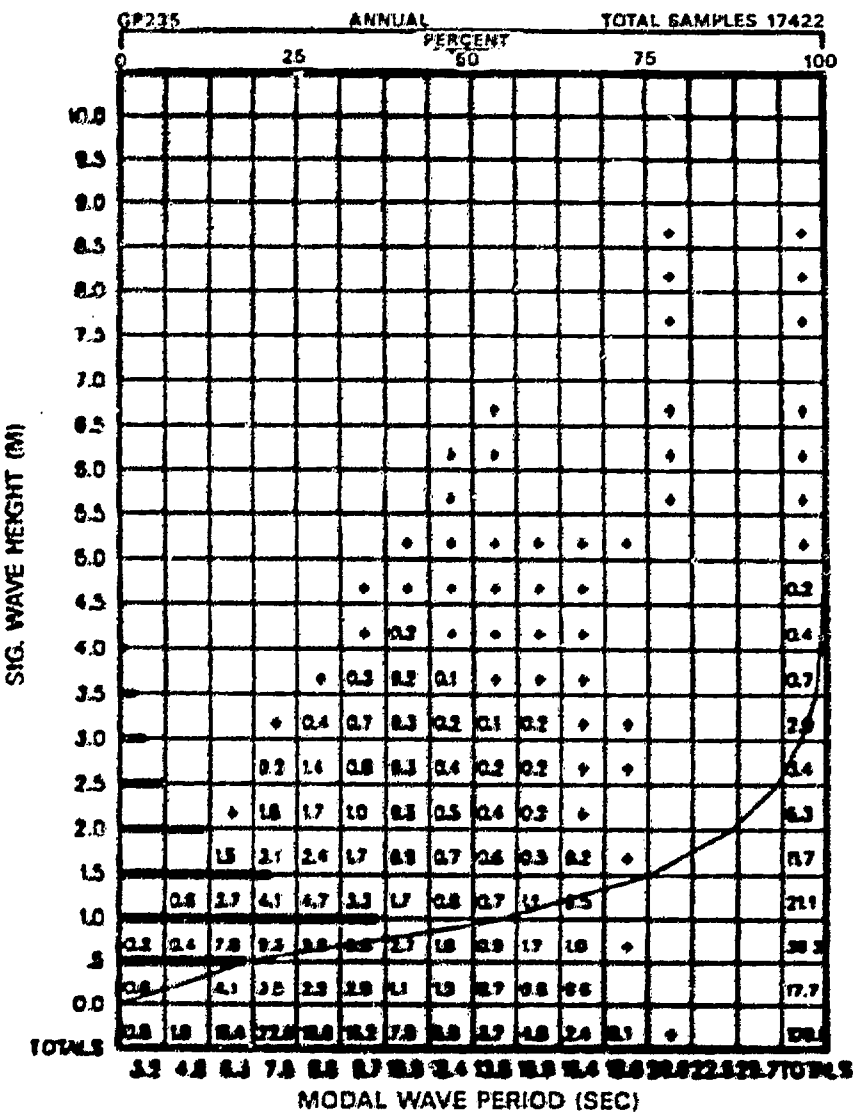


Figure A-235-1-1 Significant Wave Height vs. Modal Wave Period

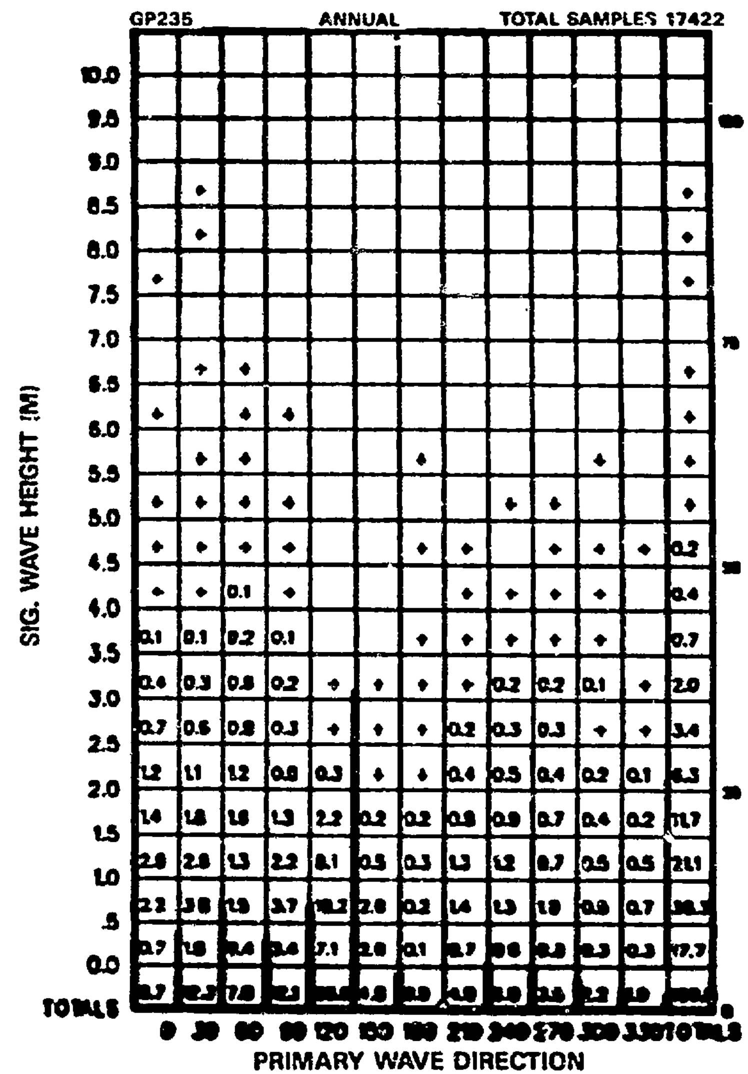


Figure A-235-1-2 Significant Wave Height vs. Primary Wave Direction

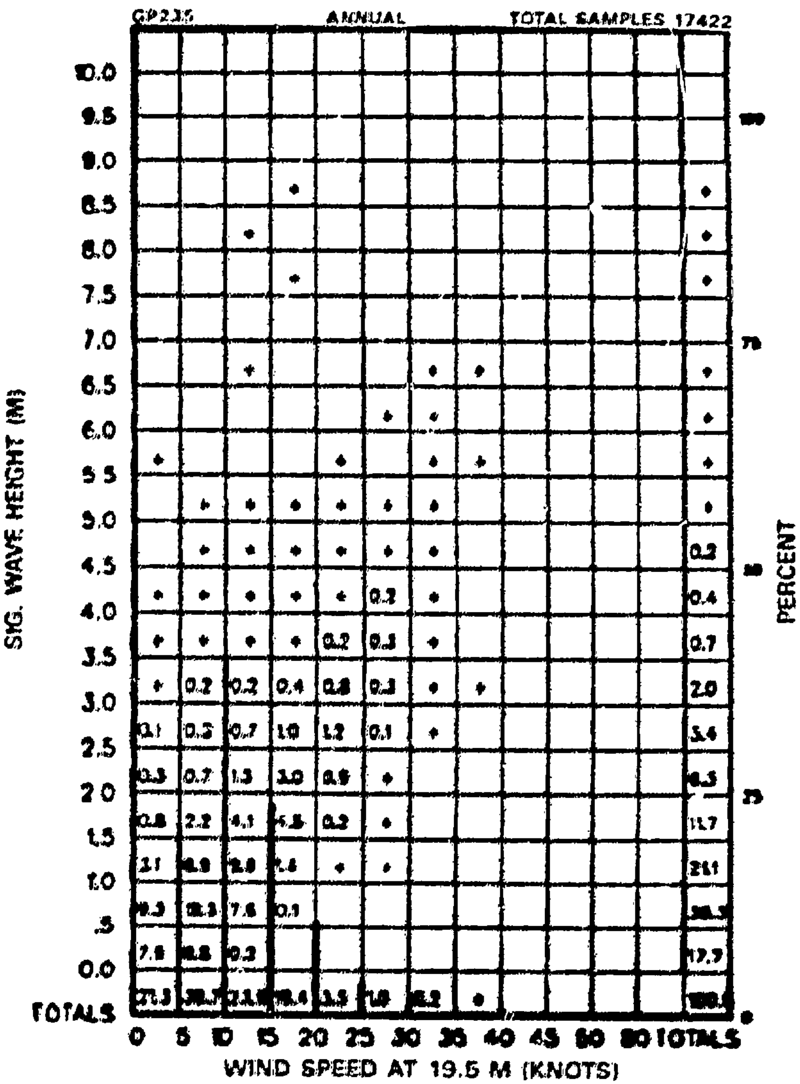


Figure A-235-1-3 Significant Wave Height vs. Wind Speed

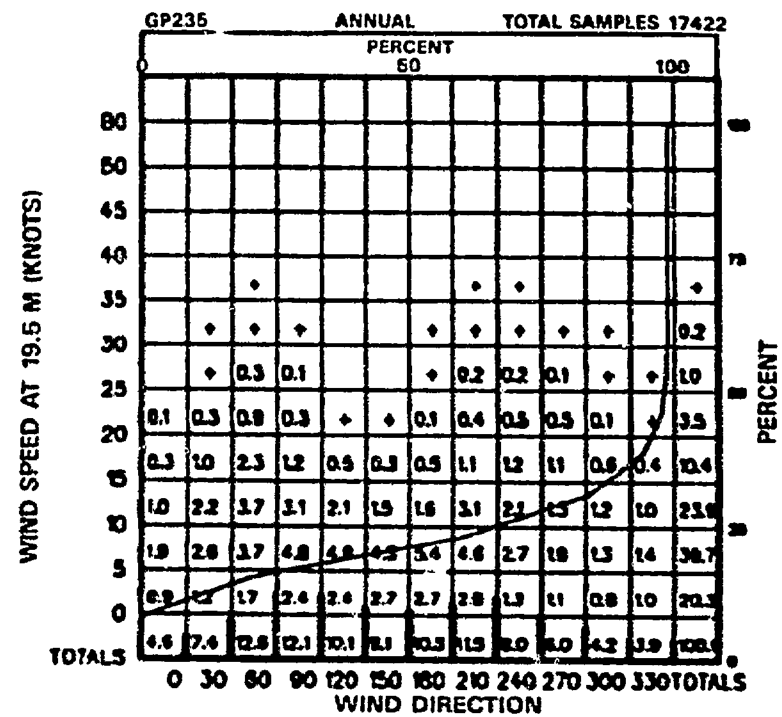


Figure A-235-1-4 Wind Speed vs. Wind Direction

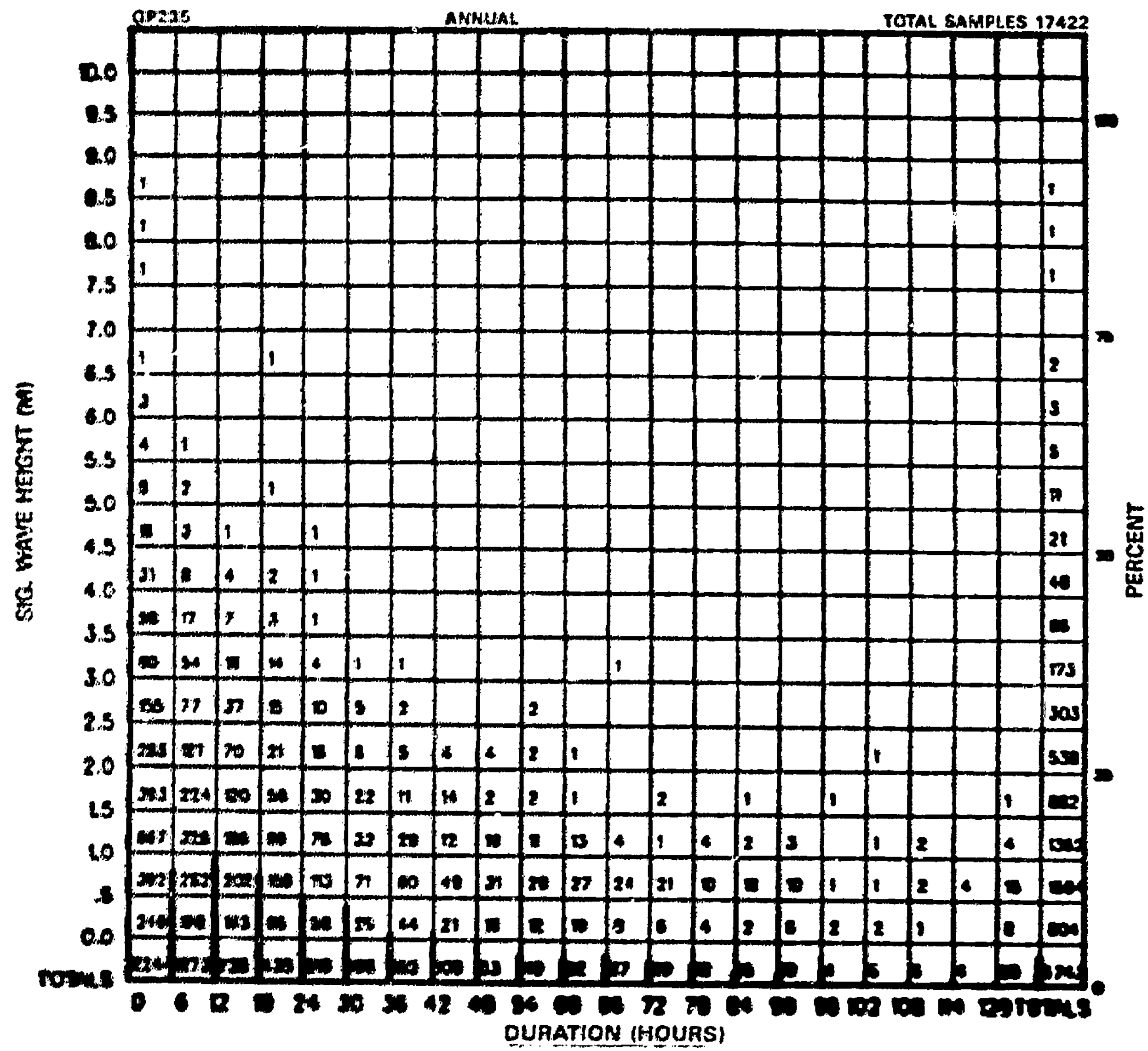


Figure A-235-1-5 Persistence of Wave Height

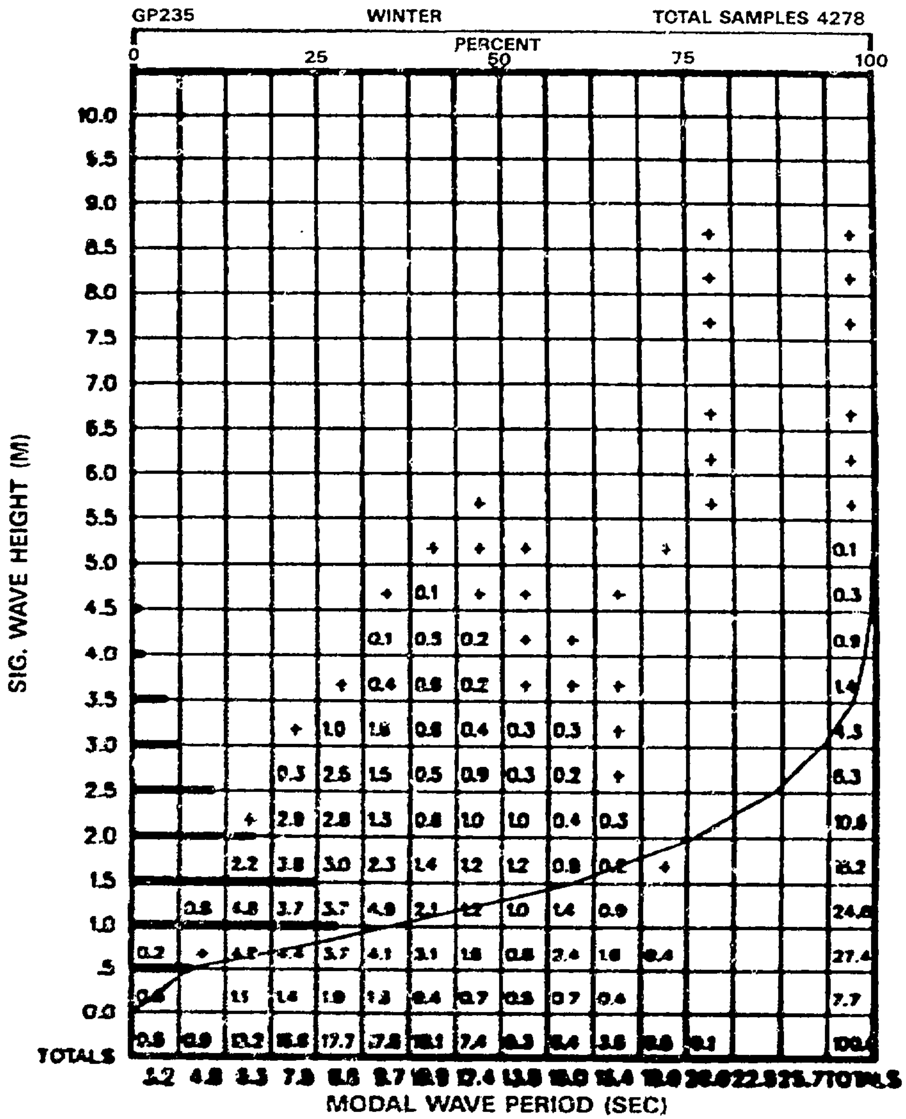


Figure A-235-2-1 Significant Wave Height vs. Modal Wave Period

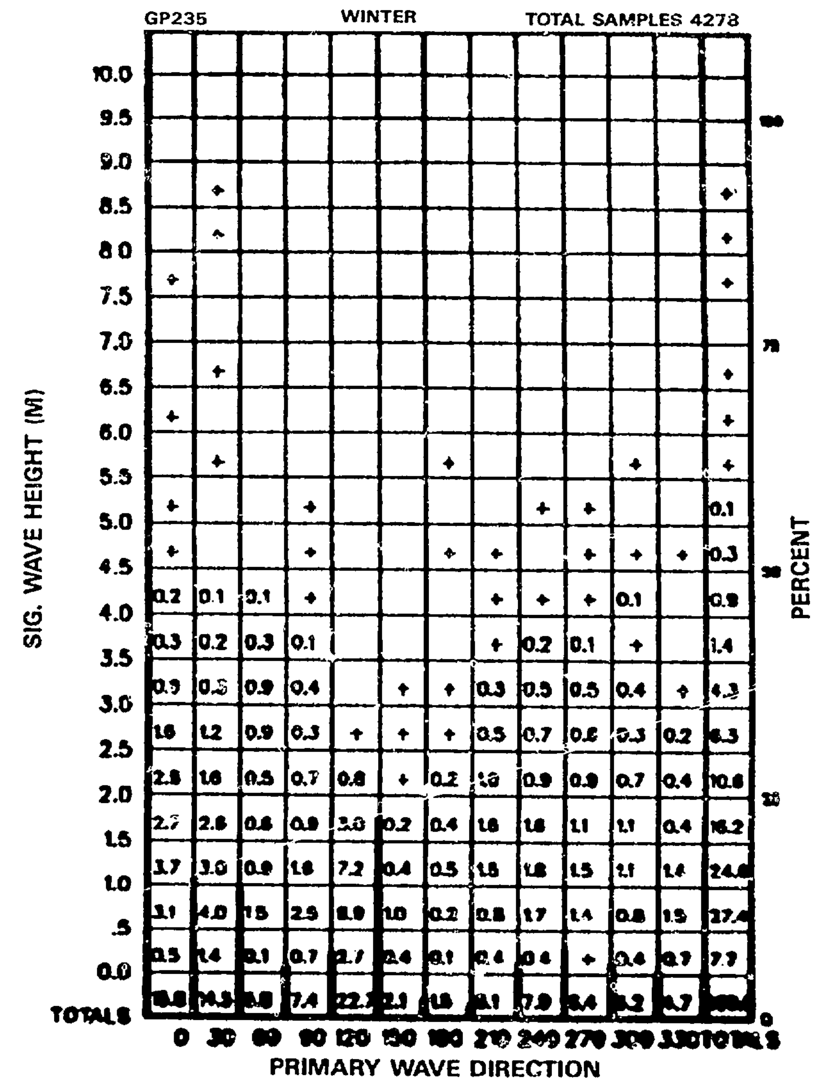


Figure A-235-2-2 Significant Wave Height vs. Primary Wave Direction

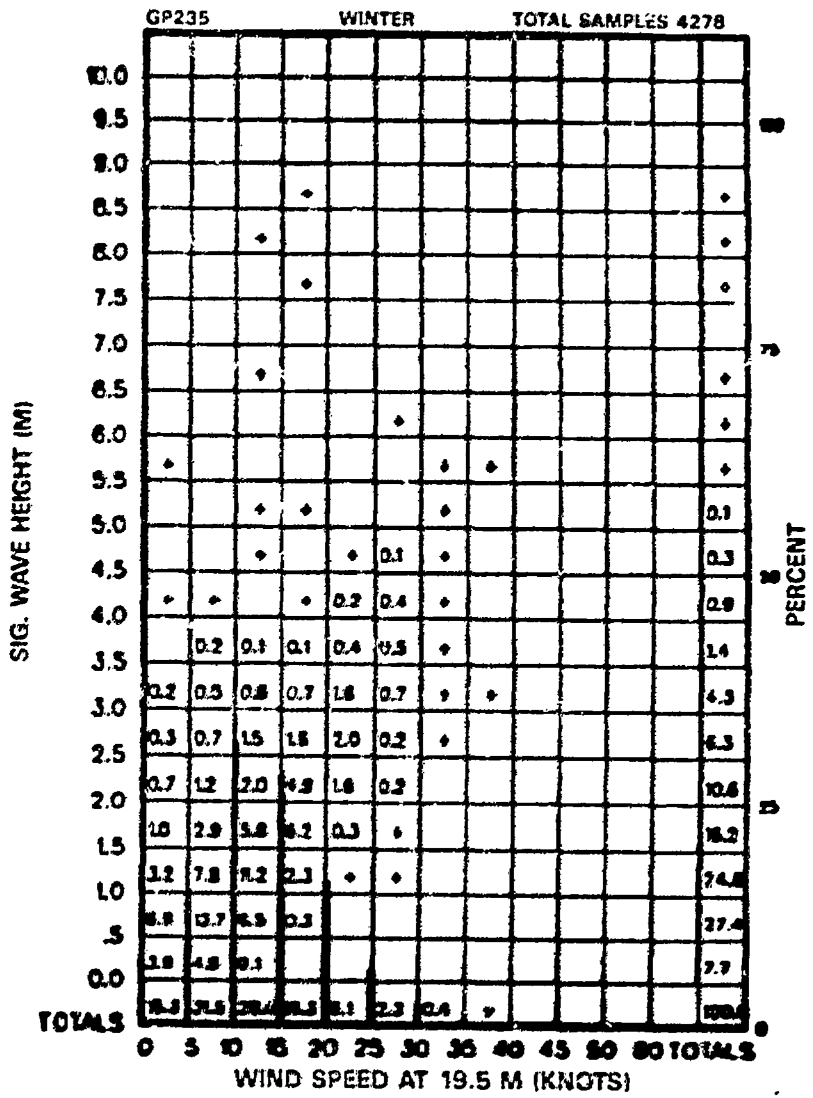


Figure A-235-2-3 Significant Wave Height vs. Wind Speed

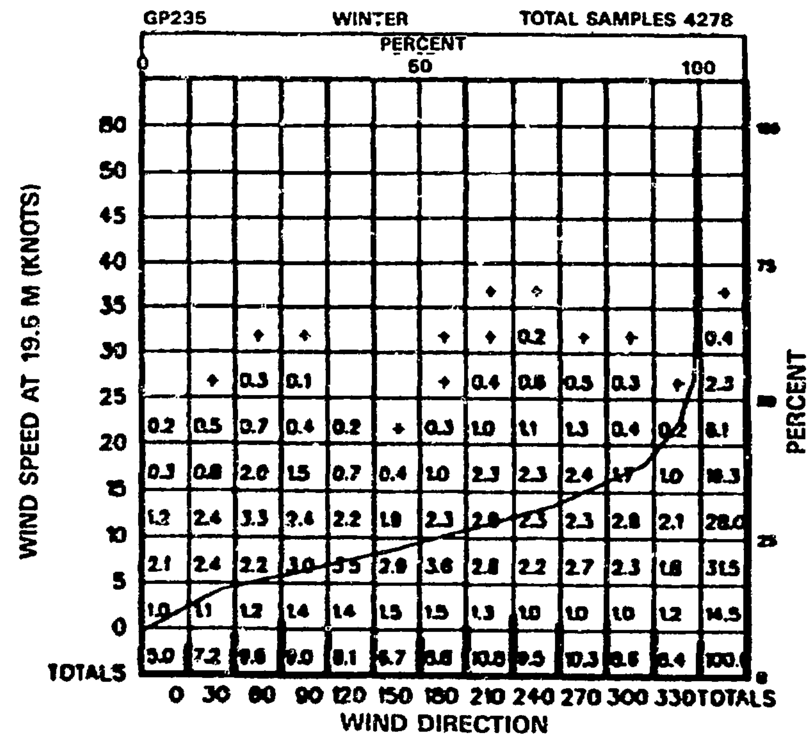


Figure A-235-2-4 Wind Speed vs. Wind Direction

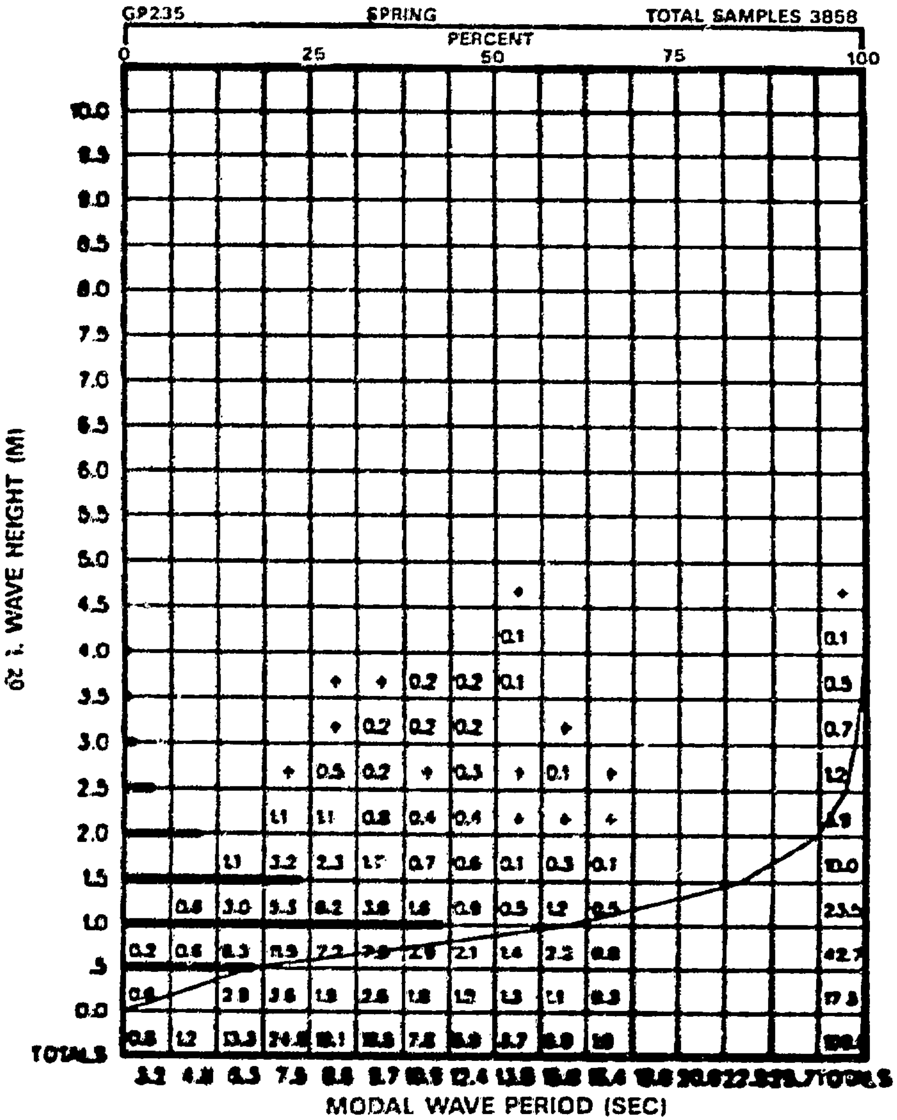


Figure A-235-3-1 Significant Wave Height vs. Modal Wave Period

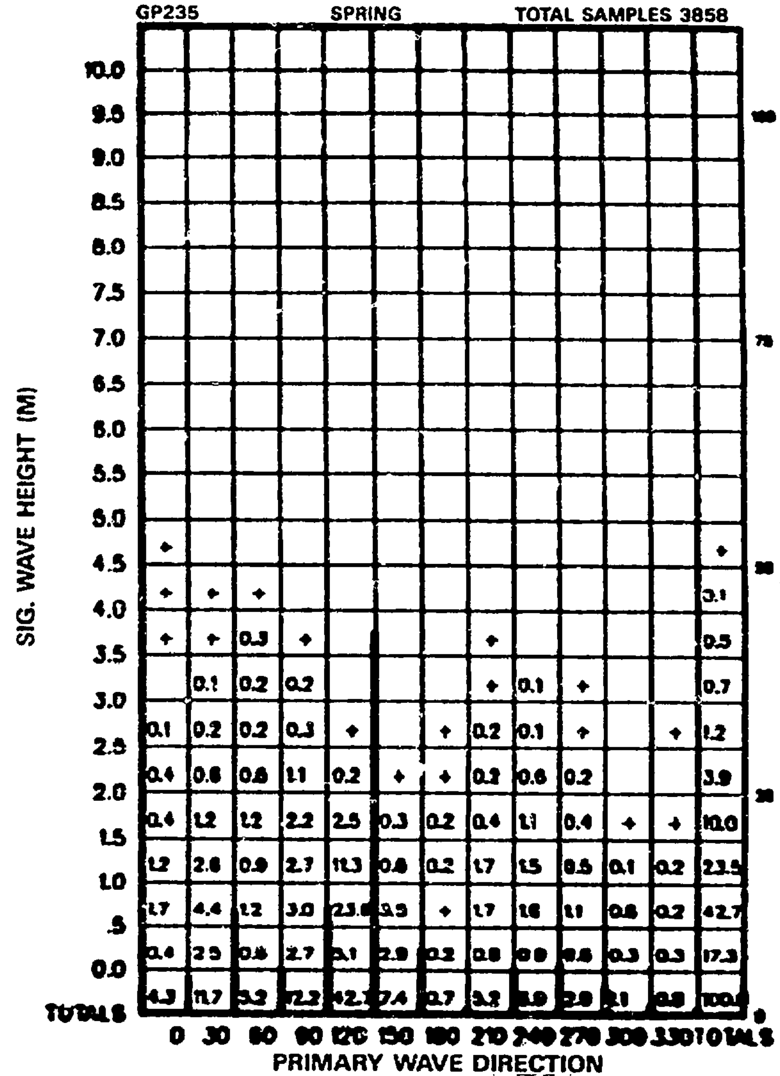


Figure A-235-3-2 Significant Wave Height vs. Primary Wave Direction

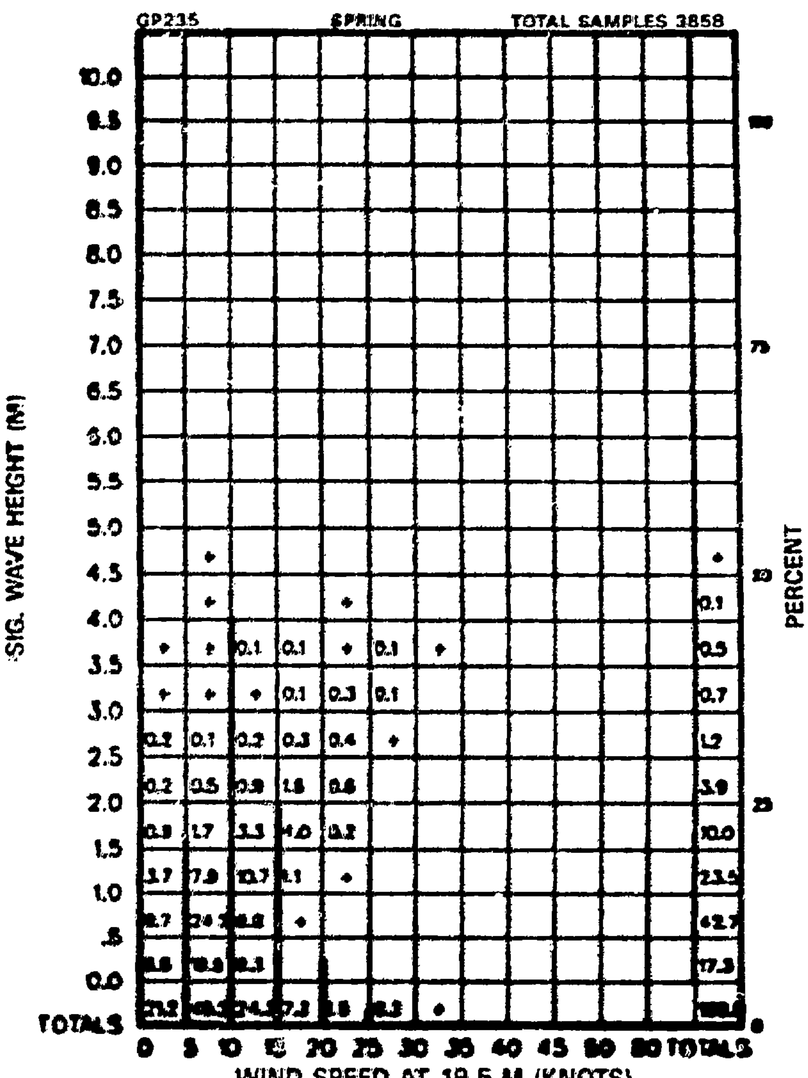


Figure A-235-3-3 Significant Wave Height vs. Wind Speed

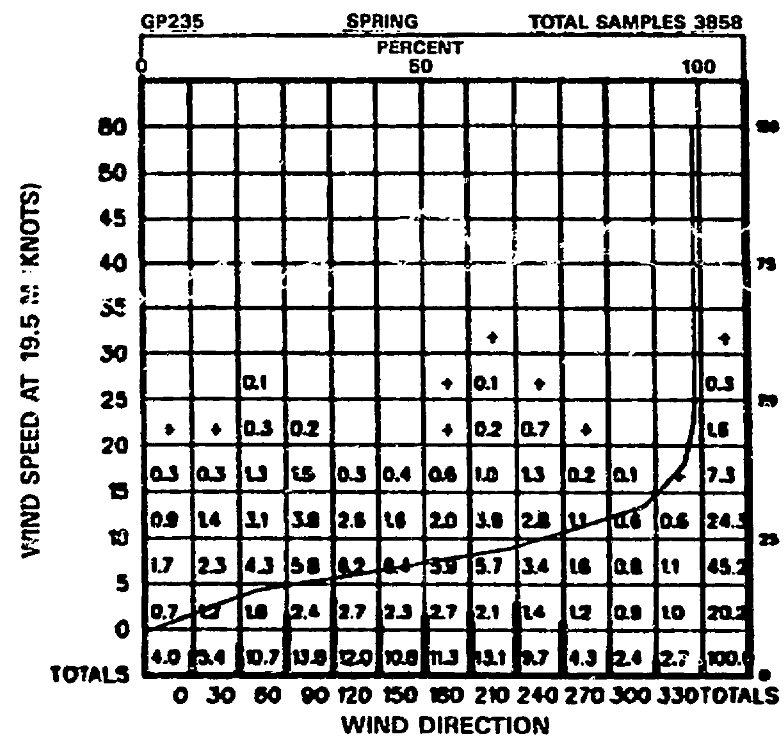


Figure A-235-3-4 Wind Speed vs. Wind Direction

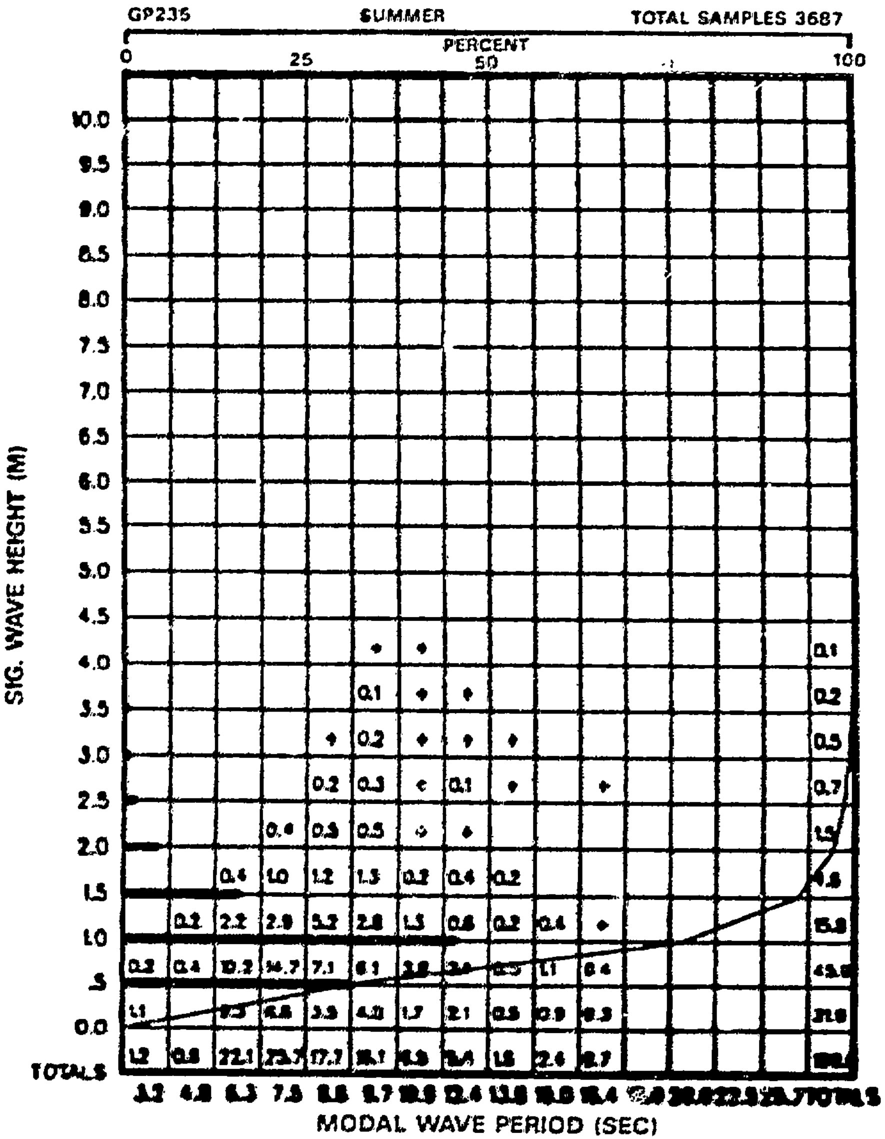


Figure A-235-4-1 Significant Wave Height vs. Modal Wave Period

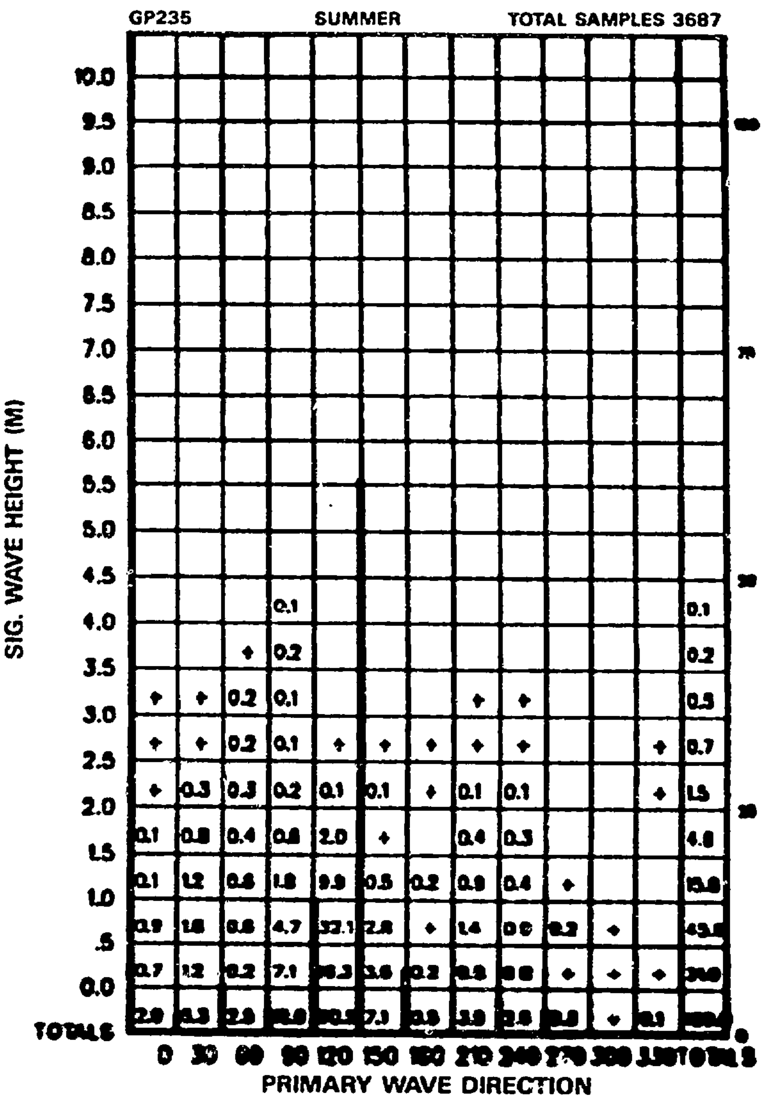


Figure A-235-4-2 Significant Wave Height vs. Primary Wave Direction

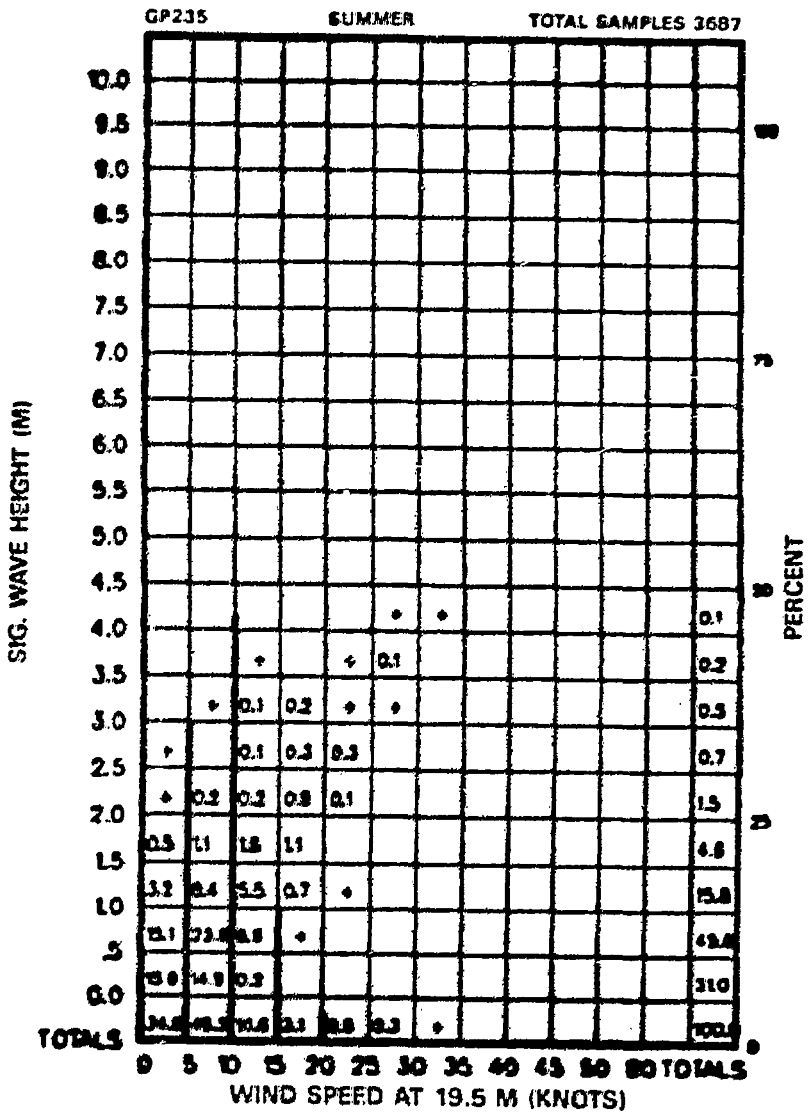


Figure A-235-4-3 Significant Wave Height vs. Wind Speed

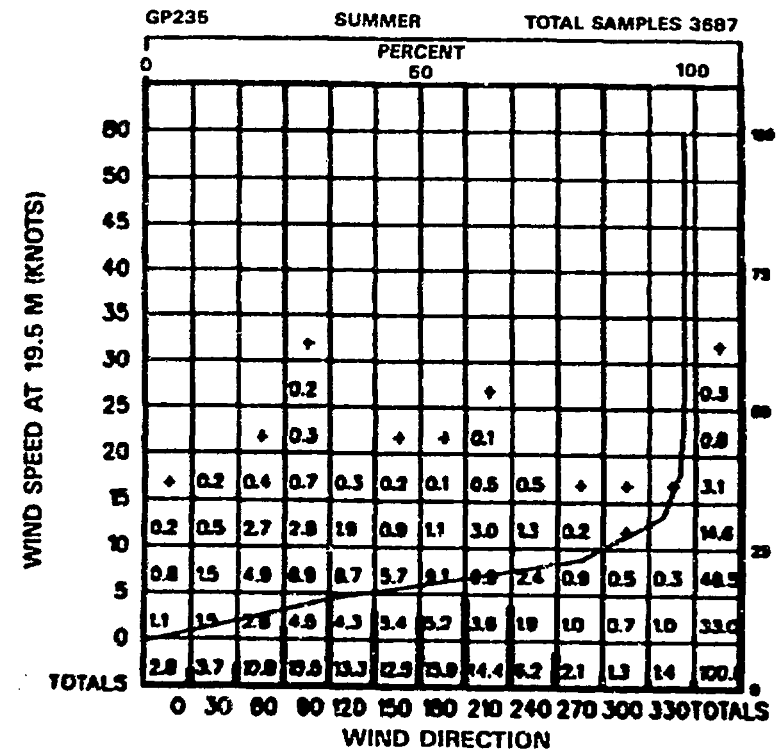


Figure A-235-4-4 Wind Speed vs. Wind Direction

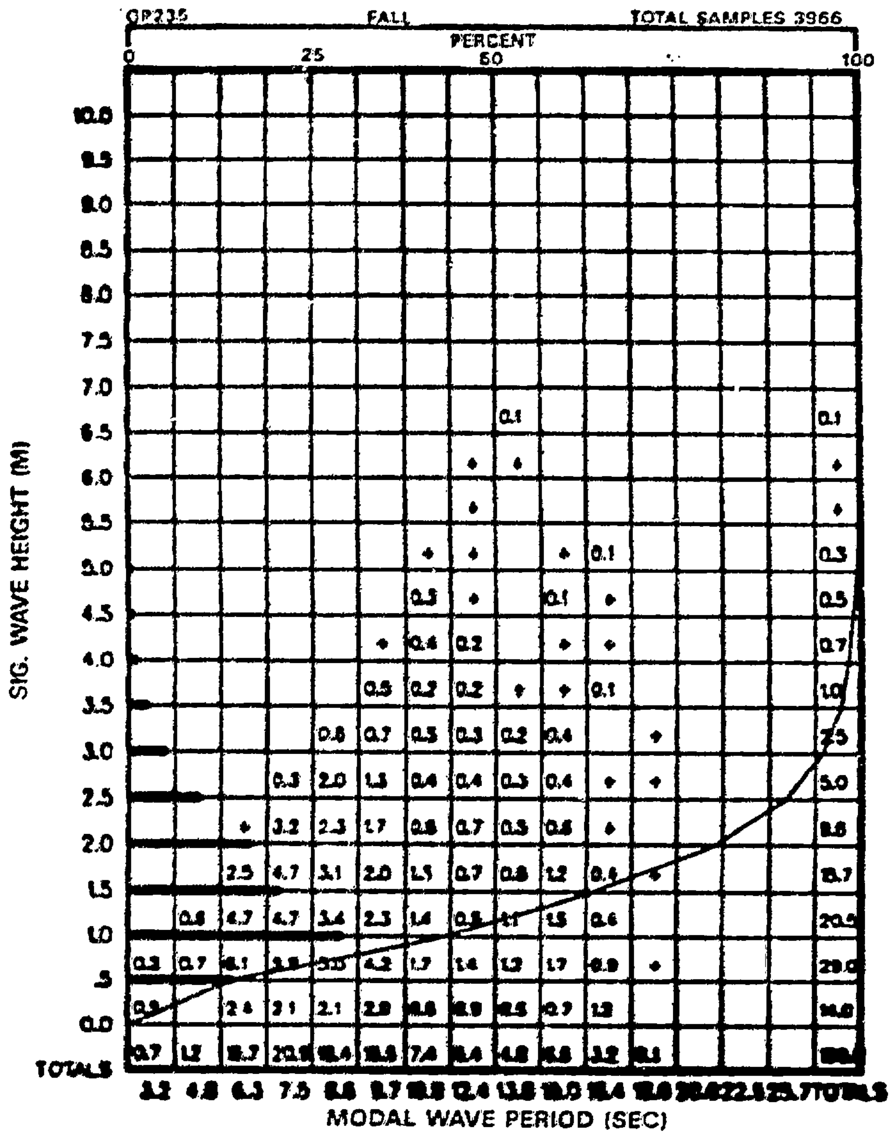


Figure A-235-5-1 Significant Wave Height vs. Modal Wave Period

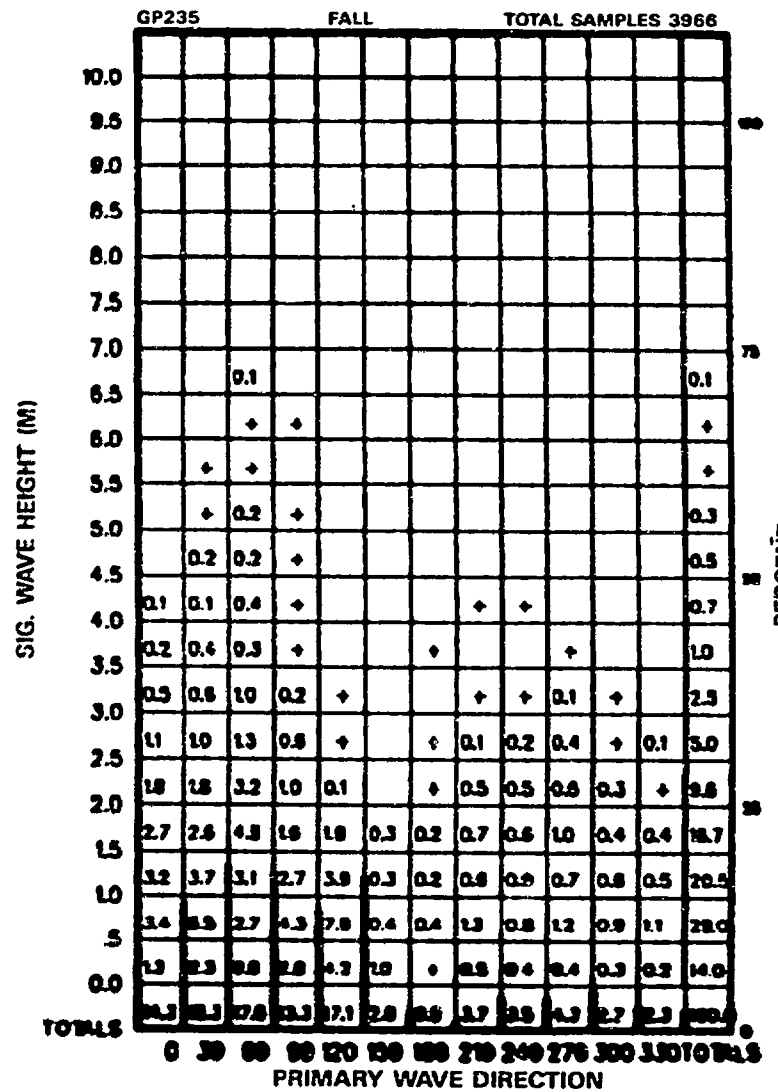


Figure A-235-5-2 Significant Wave Height vs. Primary Wave Direction

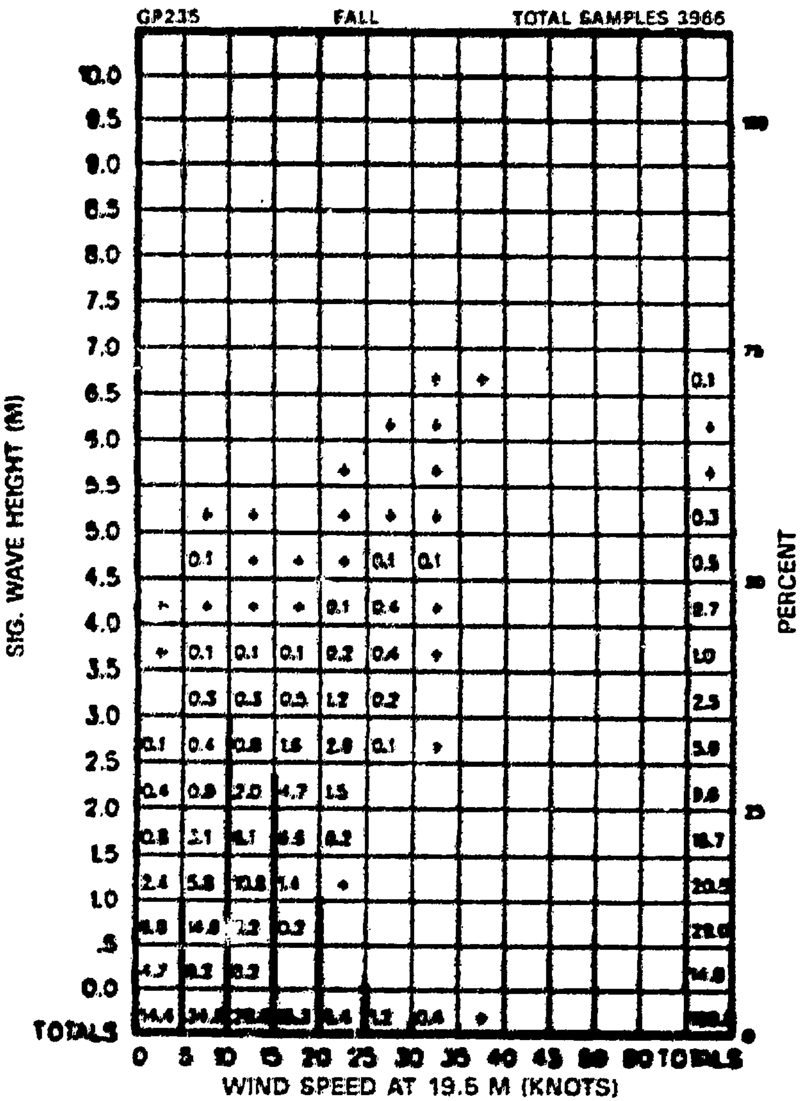


Figure A-235-5-3 Significant Wave Height vs. Wind Speed

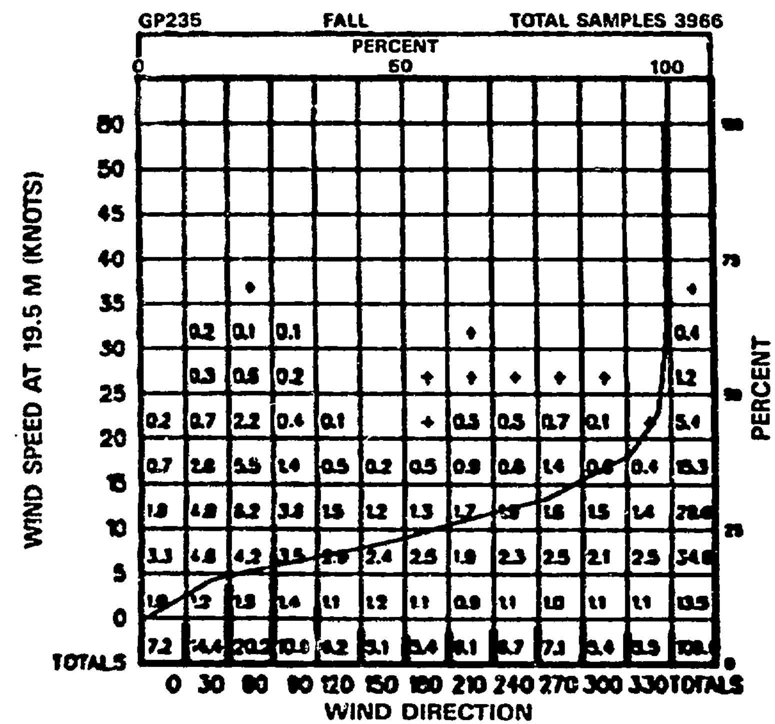


Figure A-235-5-4 Wind Speed vs. Wind Direction

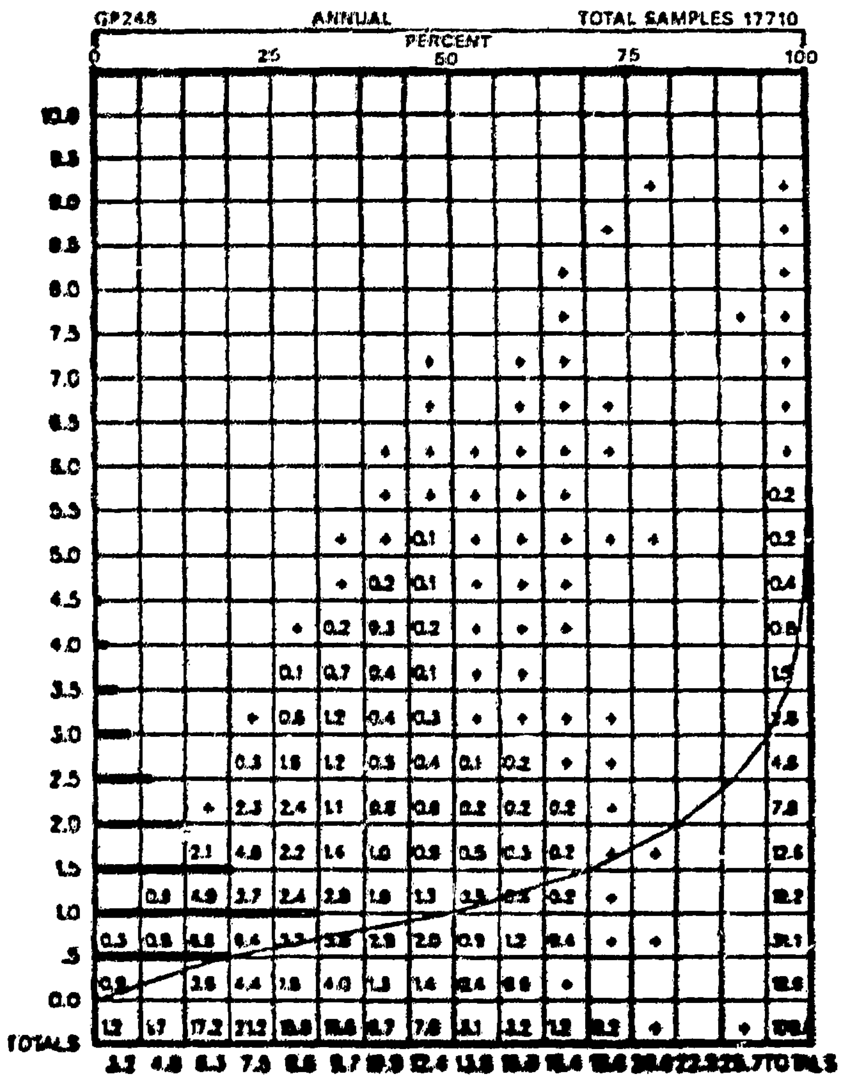


Figure A-248-1-1 Significant Wave Height vs. Modal Wave Period

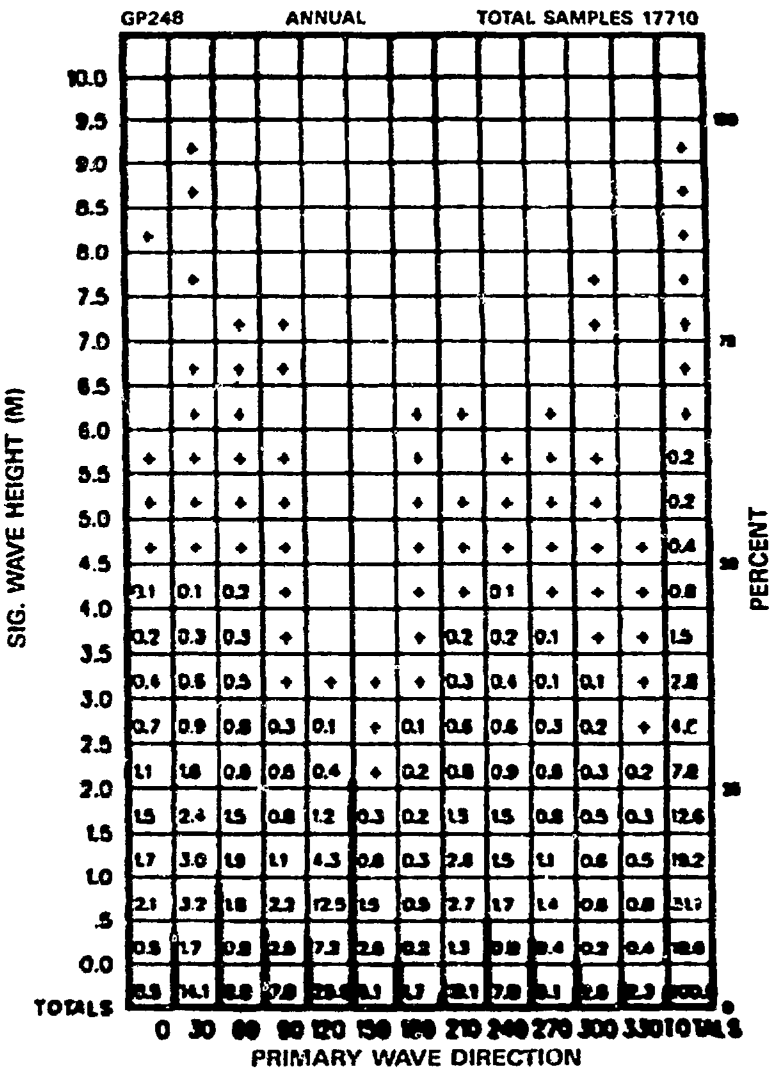


Figure A-248-1-2 Significant Wave Height vs. Primary Wave Direction

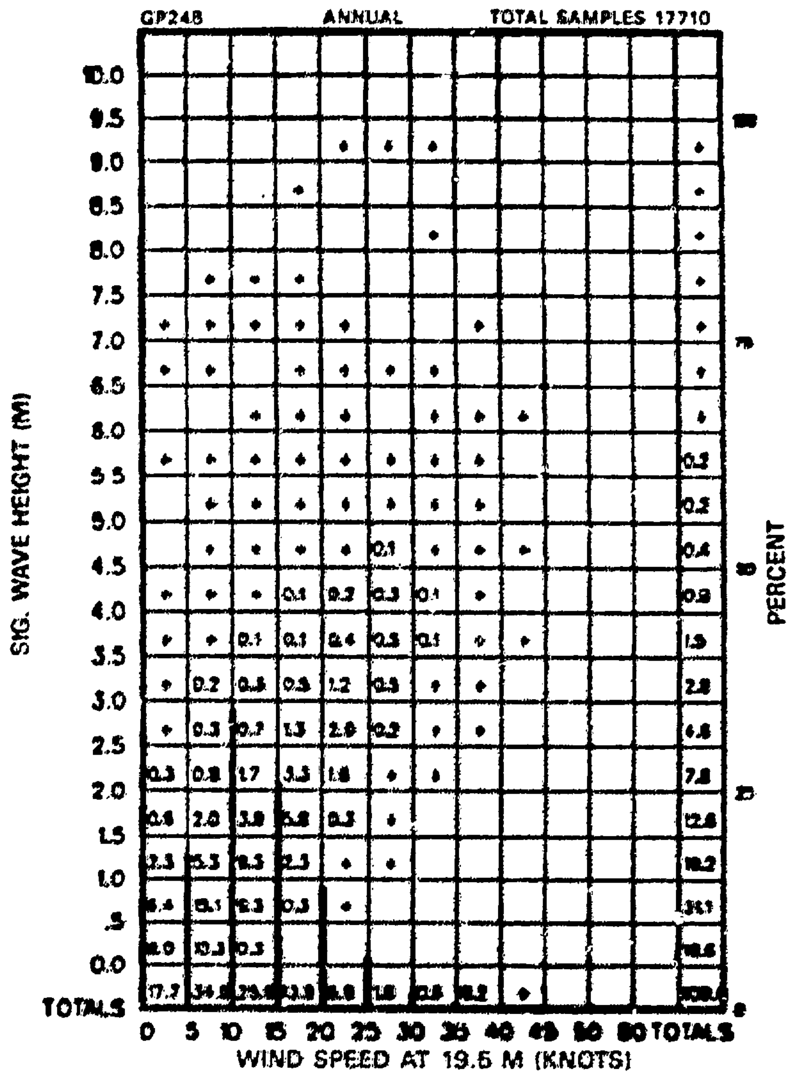


Figure A-248-1-3 Significant Wave Height vs. Wind Speed

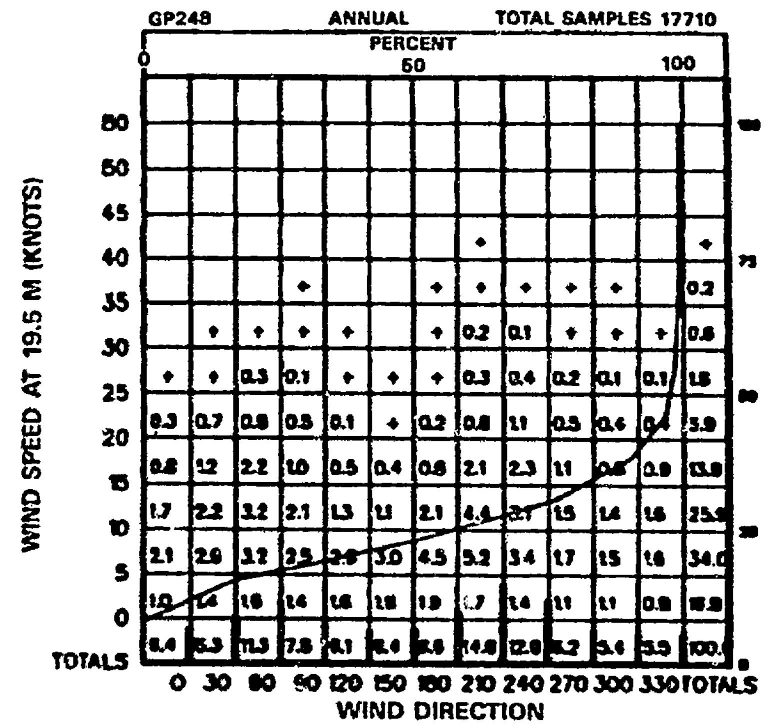


Figure A-248-1-4 Wind Speed vs. Wind Direction

GP248 ANNUAL TOTAL SAMPLES 17710

SIG. WAVE HEIGHT (M)	0	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	TOTALS
10.0																						
9.5																						
9.0			1																			1
8.5	1																					1
8.0	1																					1
7.5	3																					3
7.0	2		1	1																		4
6.5	5	2																				7
6.0	5	2			1																	8
5.5	11	5		2																		18
5.0	25	3	3	1																		32
4.5	33	15			1																	49
4.0	70	17	8	1		1																97
3.5	103	32	18	4	2			1														161
3.0	180	62	24	8	6	3	3	1														292
2.5	314	88	48	18	4	9	2	1		3												483
2.0	428	185	71	28	[illegible]	10	5	5	1	1				1		1					1	731
1.5	538	230	127	58	52	21	13	5	6		2		1	1								1058
1.0	867	346	311	102	86	48	19	16	9	10	8	2	6	1		1	1					1433
.5	485	340	228	138	127	80	47	37	22	25	8	13	9	11	6	4	2	1	2	1	3	1600
0.0	250	159	87	82	89	55	30	28	21	20	8	8	8	2	1	3	3	2	2	1	8	847
TOTALS	3725	3482	[illegible]	1444	[illegible]	219	[illegible]	[illegible]	[illegible]	37	22	21	21	[illegible]	7	[illegible]	[illegible]	3	4	2	12	[illegible]

DURATION (HOURS)

PERCENT: 100, 75, 50, 25, 0

Figure A-248-1-5 Persistence of Wave Height

GP248 ANNUAL TOTAL SAMPLES 17710

WIND SPEED AT 19.5 M (KNOTS) \ DURATION (HOURS)	0	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	TOTALS
60																						
50																						
45																						
40	4																					4
35	16	3	2																			21
30	57	17	1	2																		77
25	130	31	12	9		1			1													204
20	[illegible]	136	84	24	16	7	1	2	2		1	1										563
15	[illegible]	284	158	73	37	14	16	12	6	4		1		1								1178
10	890	439	271	146	78	36	36	16	9	8	6	8	2	2	1	1						1953
5	878	534	280	[illegible]	99	89	32	28	18	20	16	10	6	3	6	2		1	3		3	220[illegible]
0	381	[illegible]	174	75	36	37	27	18	18	9	12	4	8	4		2			1		1	1031
TOTALS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	132	79	56	41	25	24	18	10	7	5		1	4		4	7235

PERCENT: 100, 75, 50, 25, 0

Figure A-248.1-6 Persistence of Wind Speed

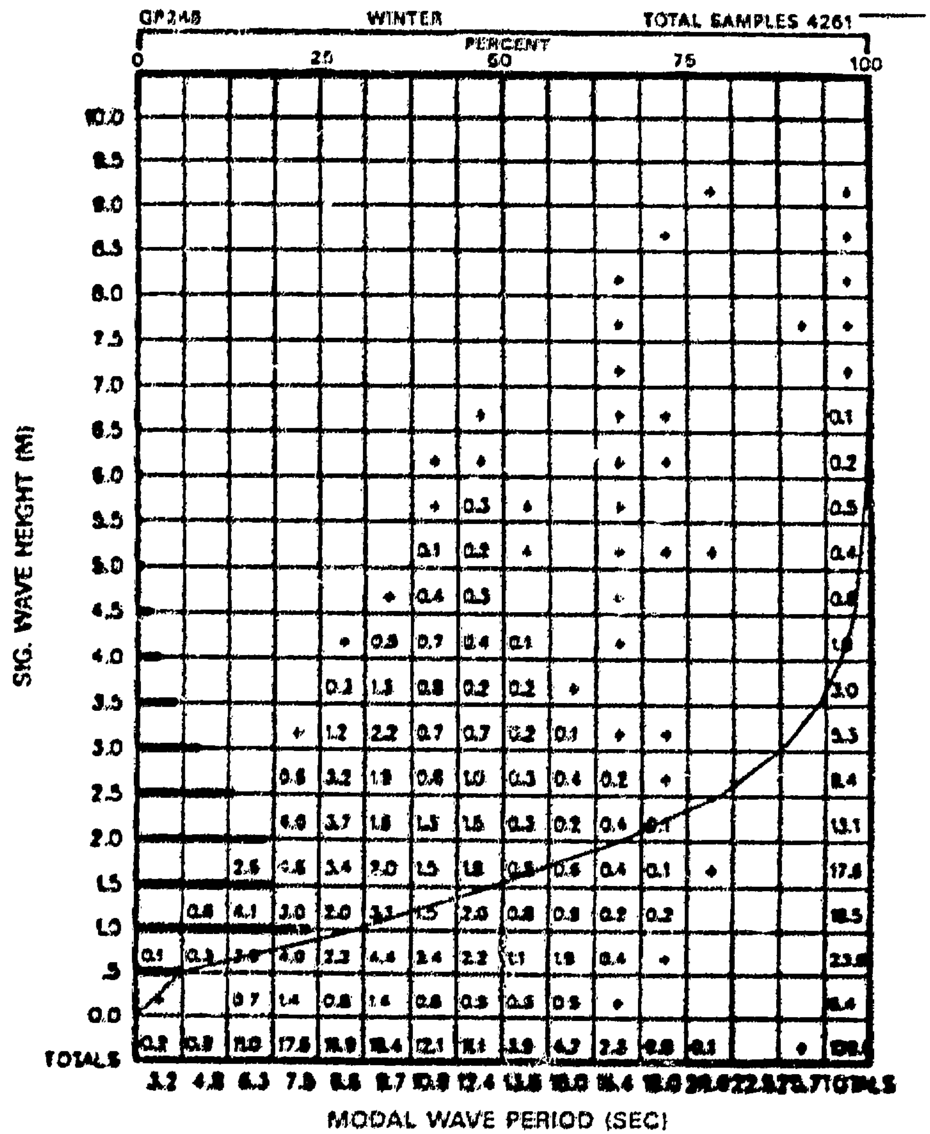


Figure A-248-2-1 Significant Wave Height vs. Modal Wave Period

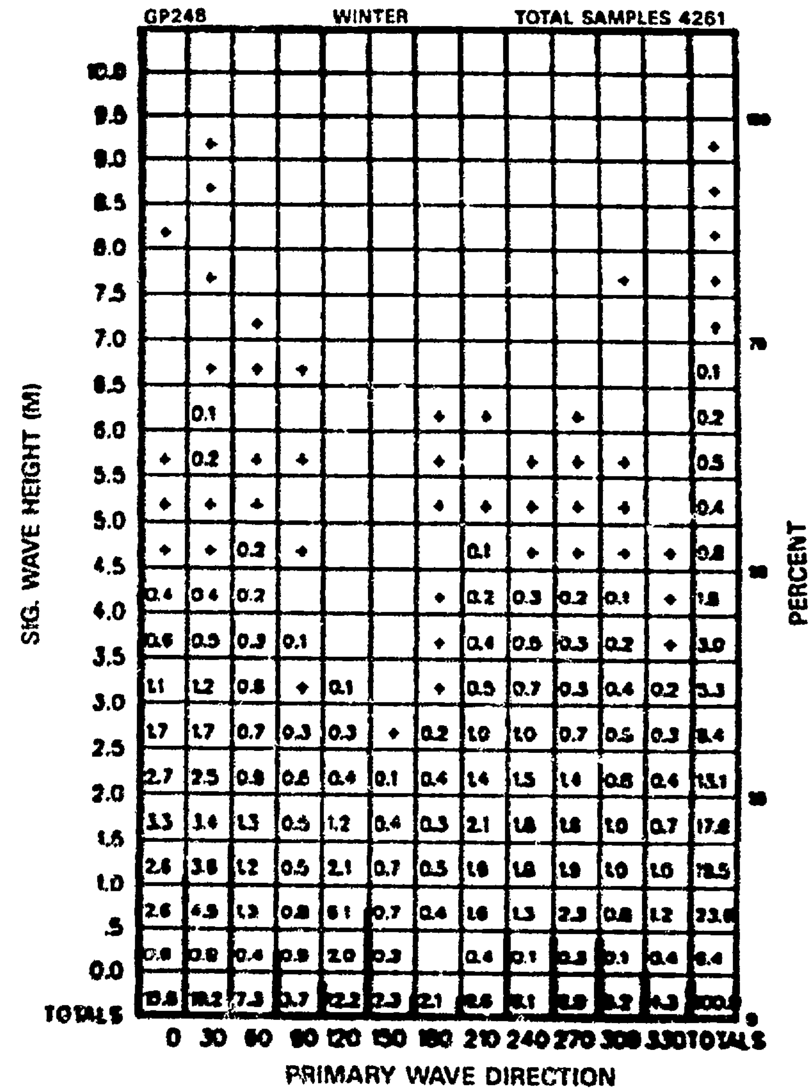


Figure A-248-2-2 Significant Wave Height vs. Primary Wave Direction

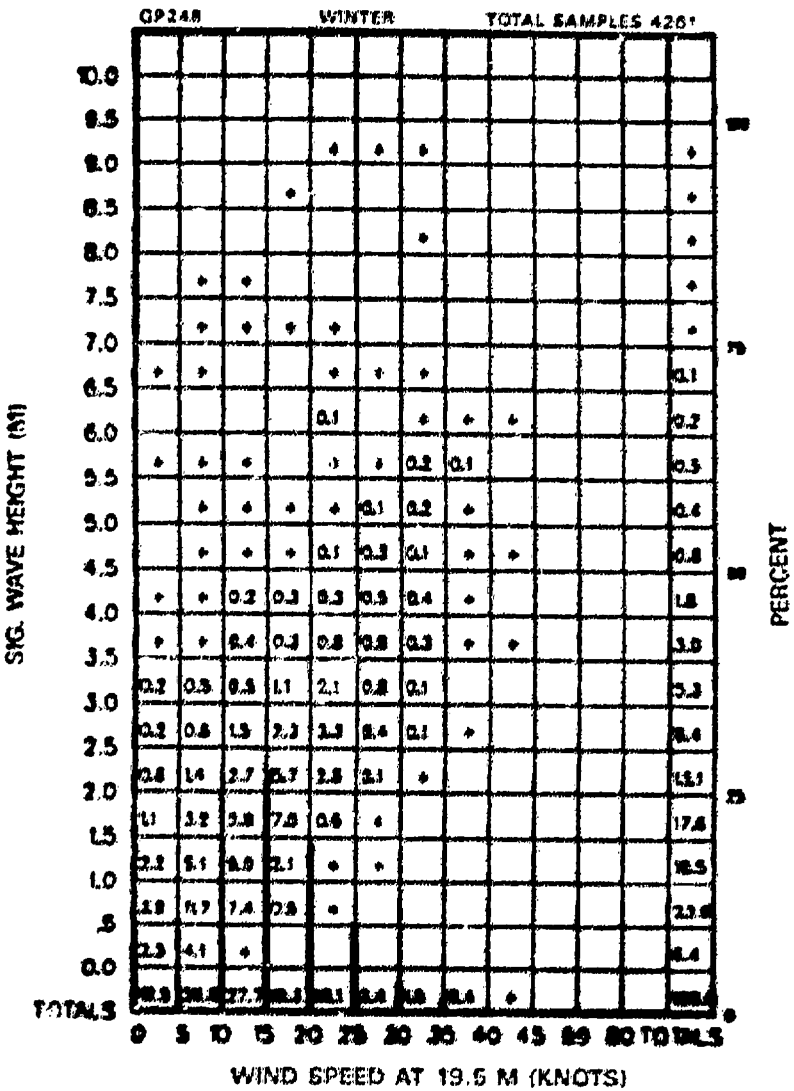


Figure A-248-2-3 Significant Wave Height vs. Wind Speed

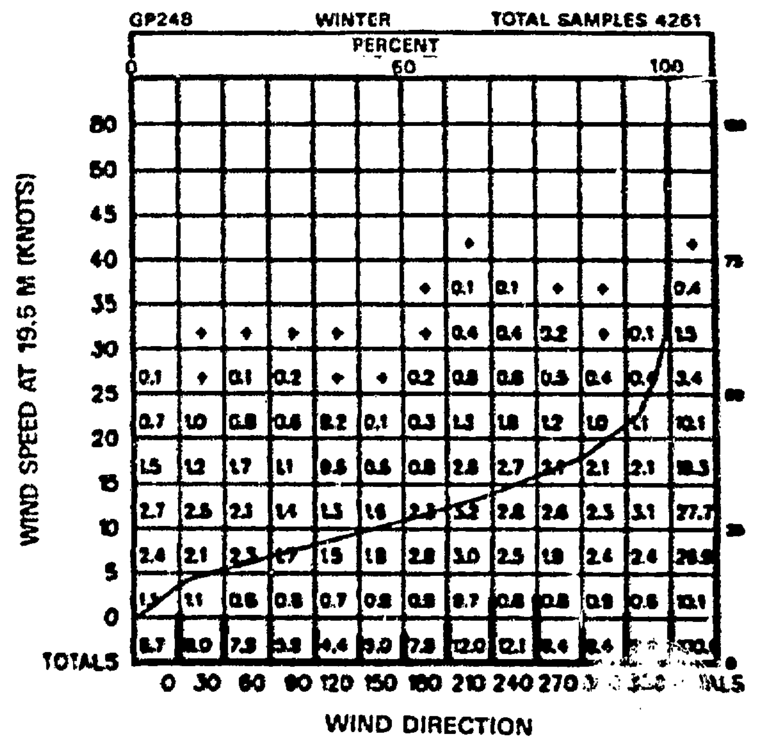


Figure A-248-2-4 Wind Speed vs. Wind Direction

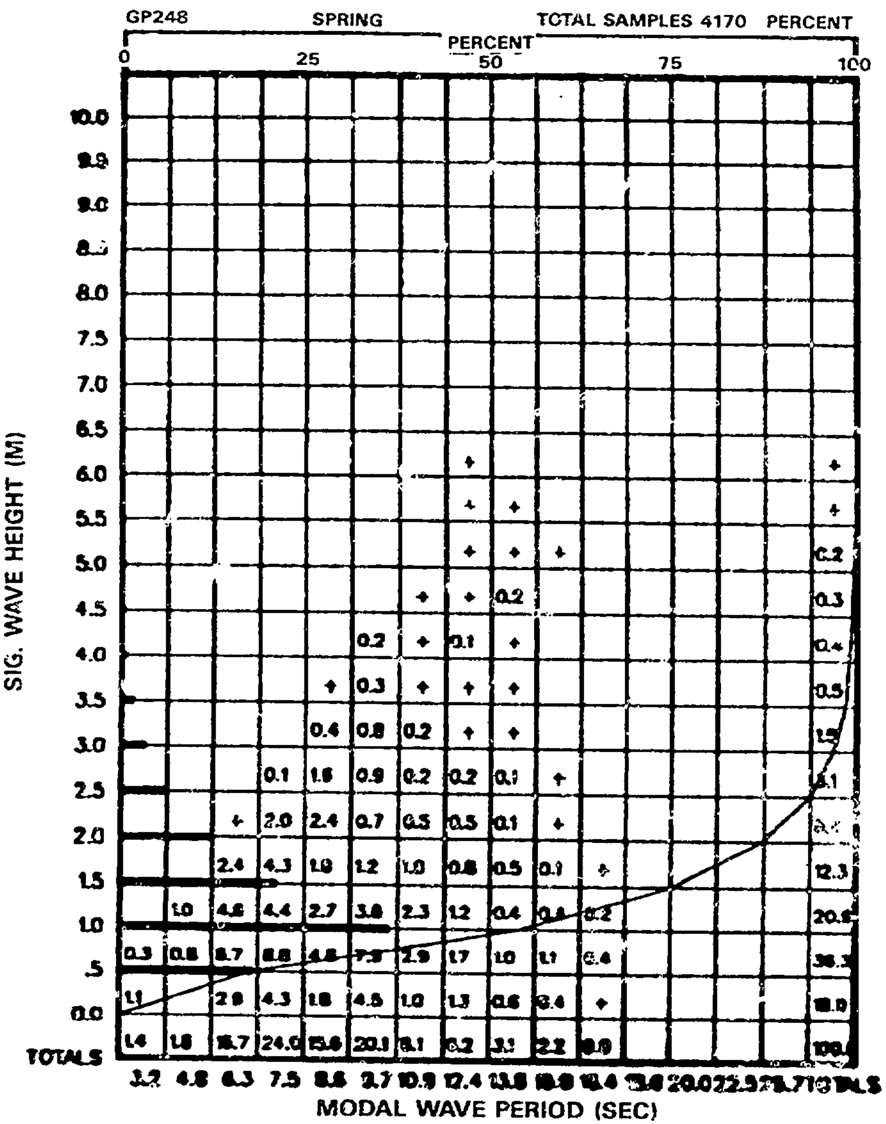


Figure A-248-3-1 Significant Wave Height vs. Modal Wave Period

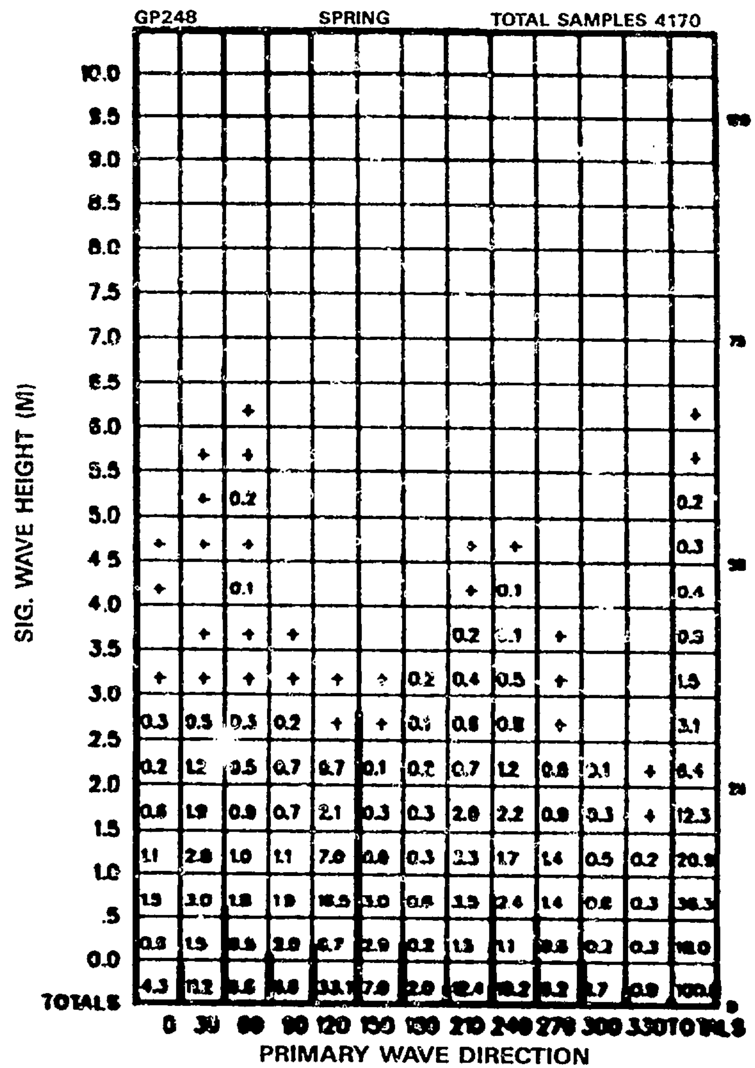


Figure A-248-3-2 Significant Wave Height vs. Primary Wave Direction

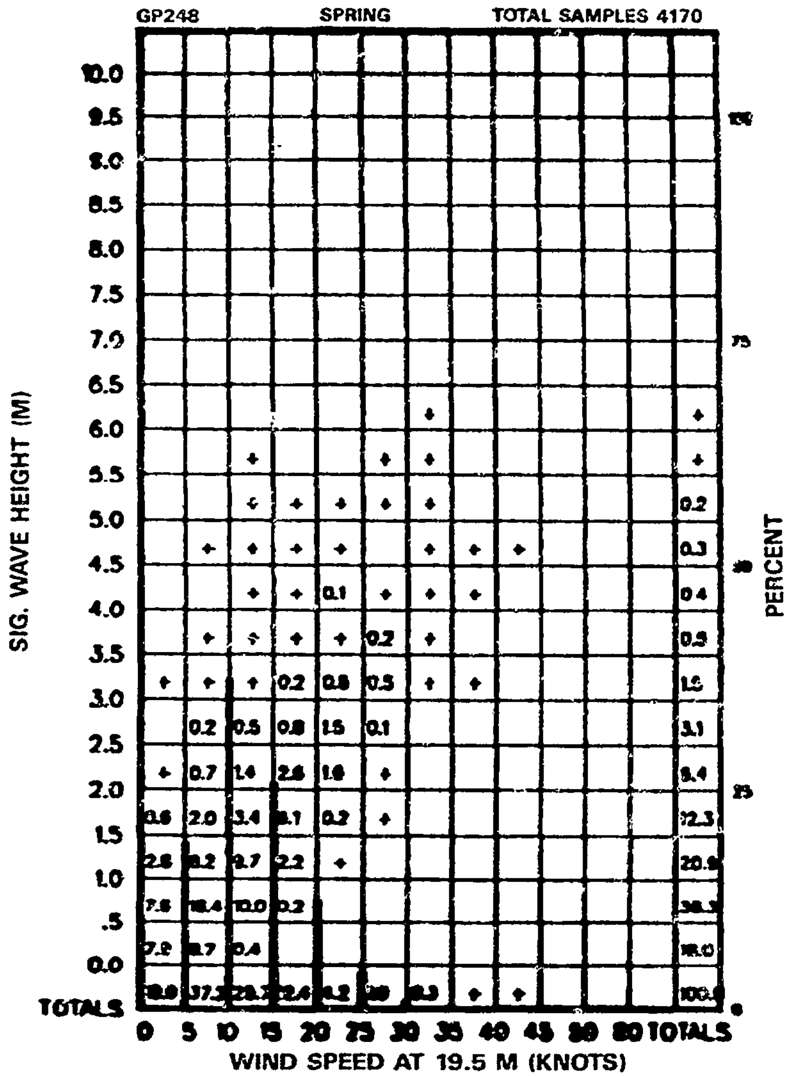


Figure A-248-3-3 Significant Wave Height vs. Wind Speed

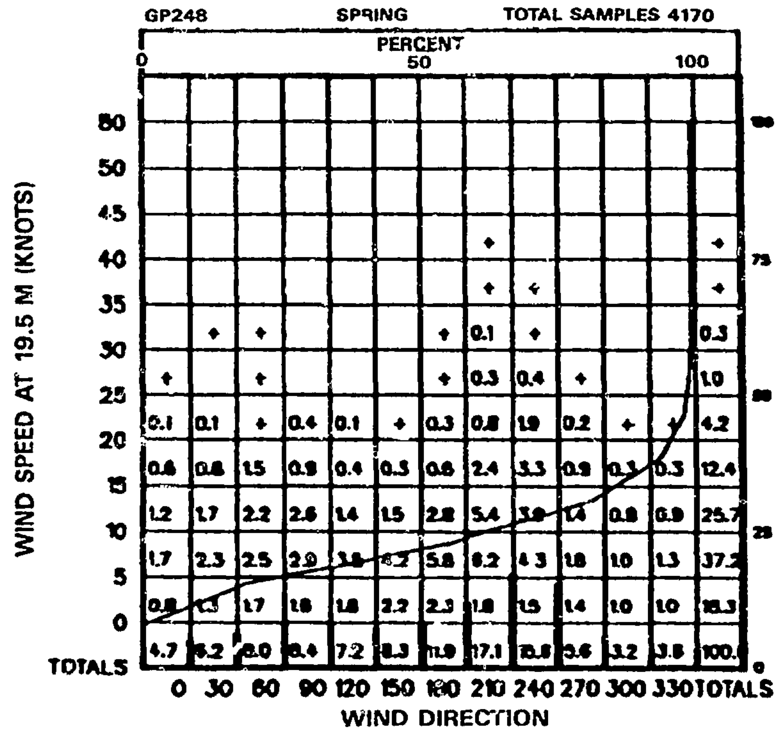


Figure A-248-3-4 Wind Speed vs. Wind Direction

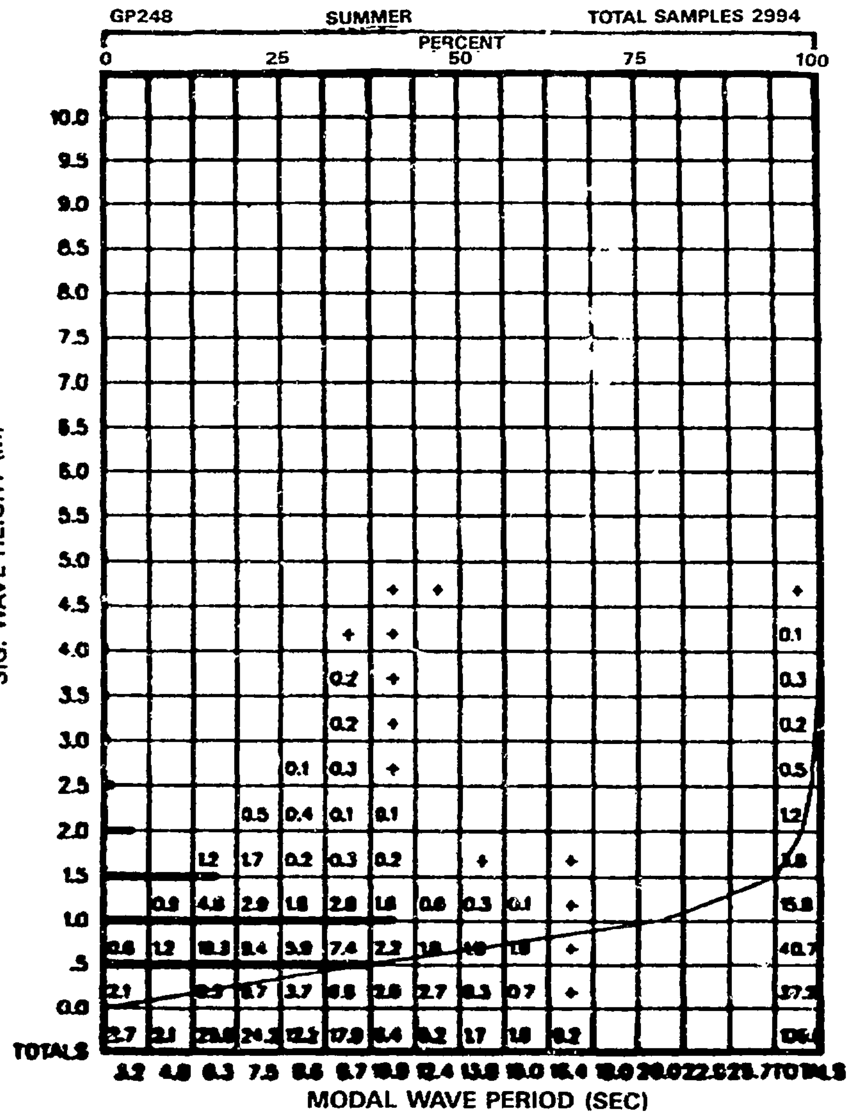


Figure A-248-4-1 Significant Wave Height vs. Modal Wave Period

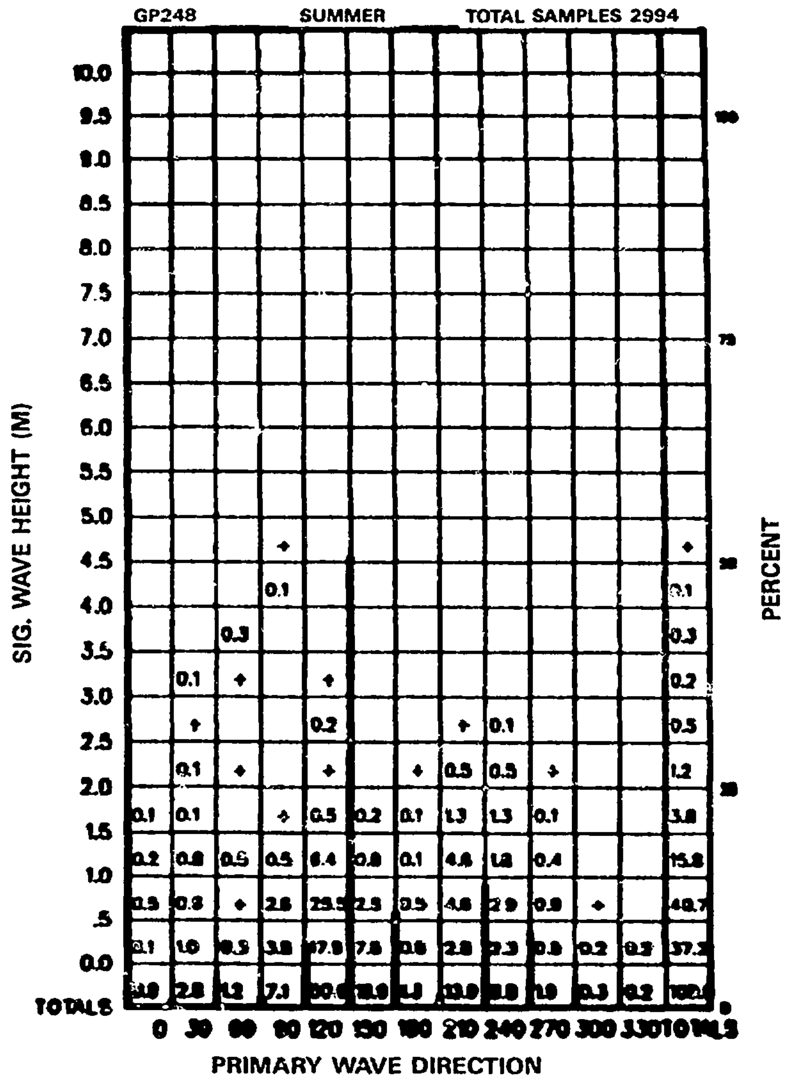


Figure A-248-4-2 Significant Wave Height vs. Primary Wave Direction

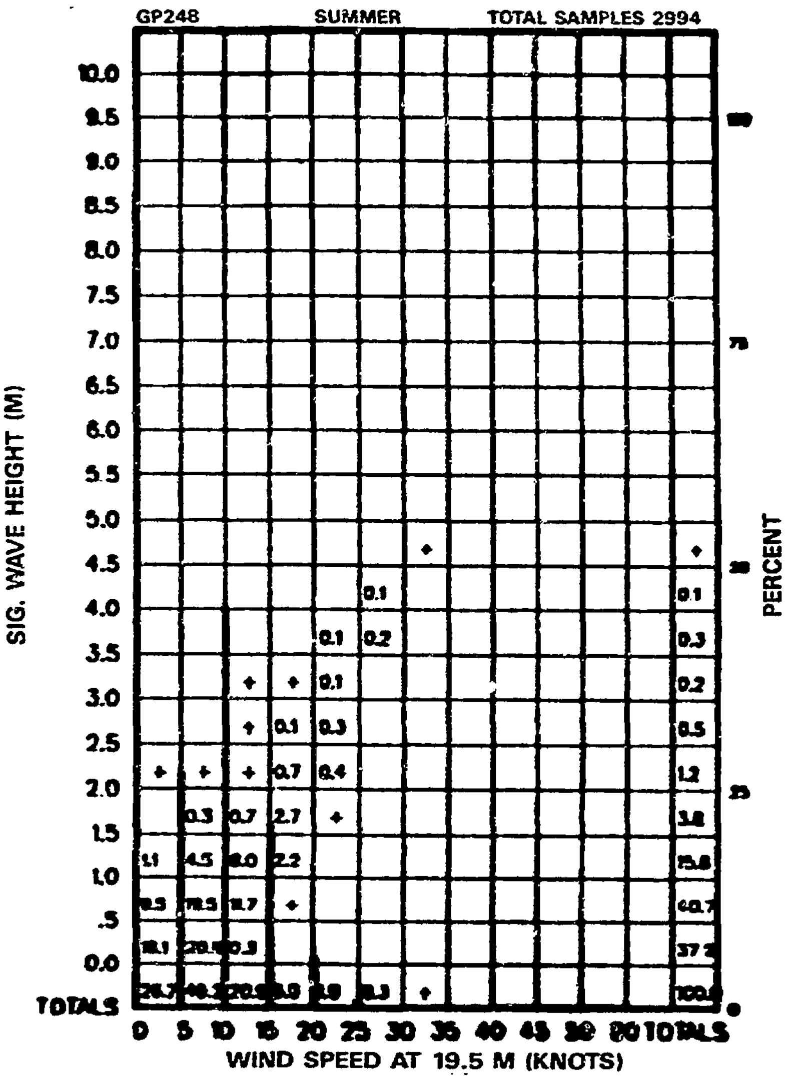


Figure A-248-4-3 Significant Wave Height vs. Wind Speed

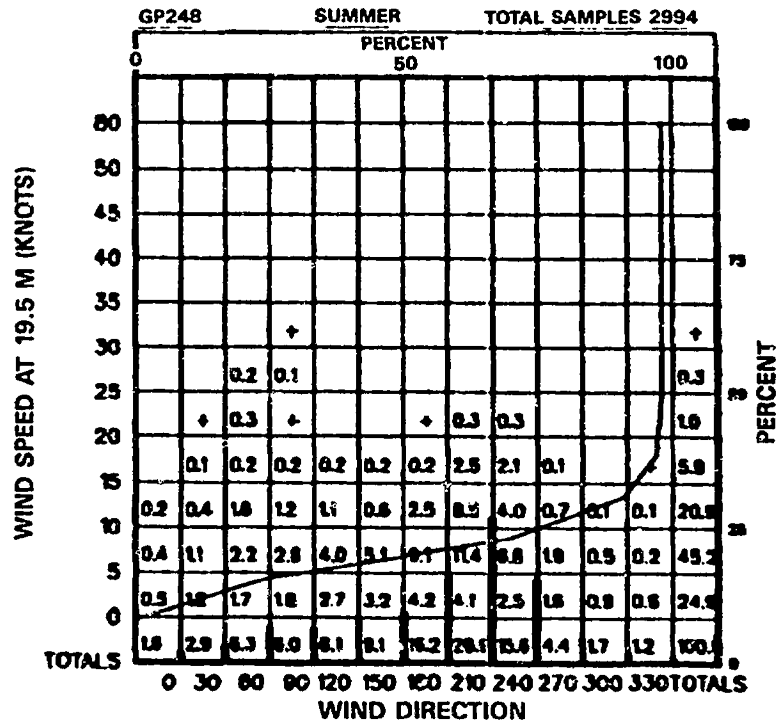


Figure A-248-4-4 Wind Speed vs. Wind Direction

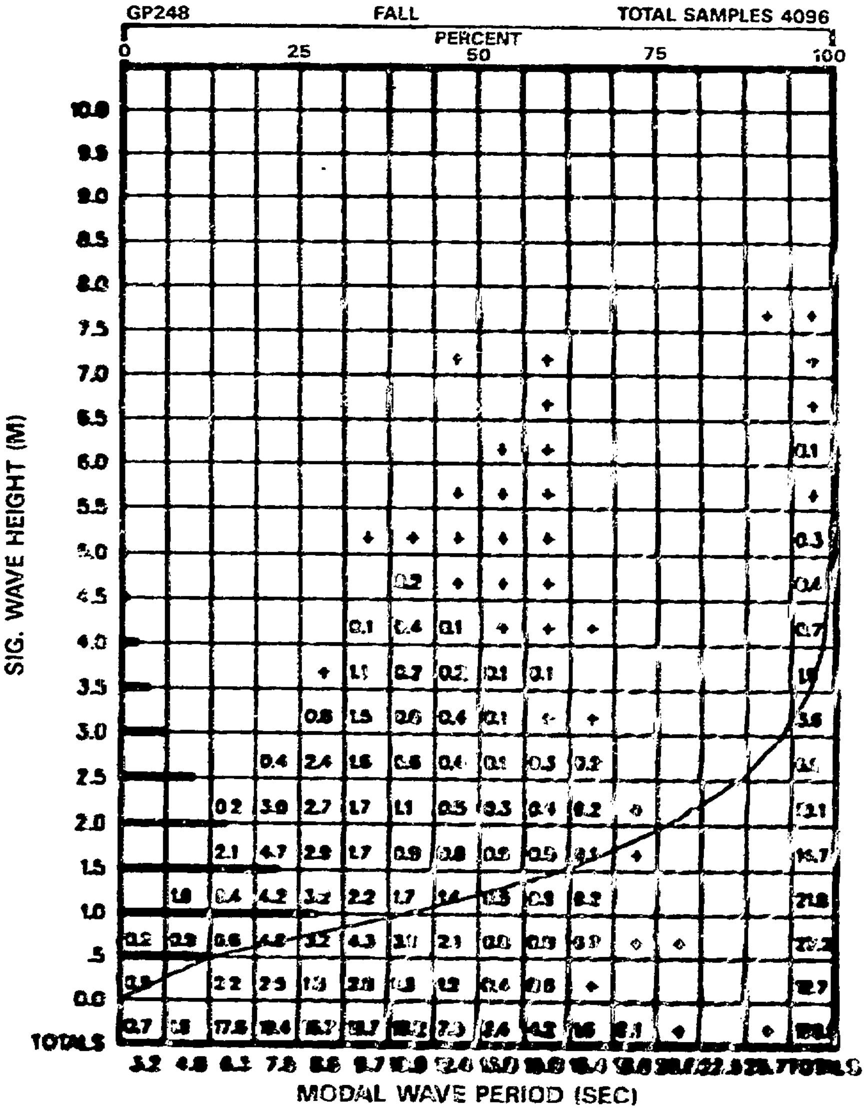


Figure A-248-5-1 Significant Wave Height vs. Modal Wave Period

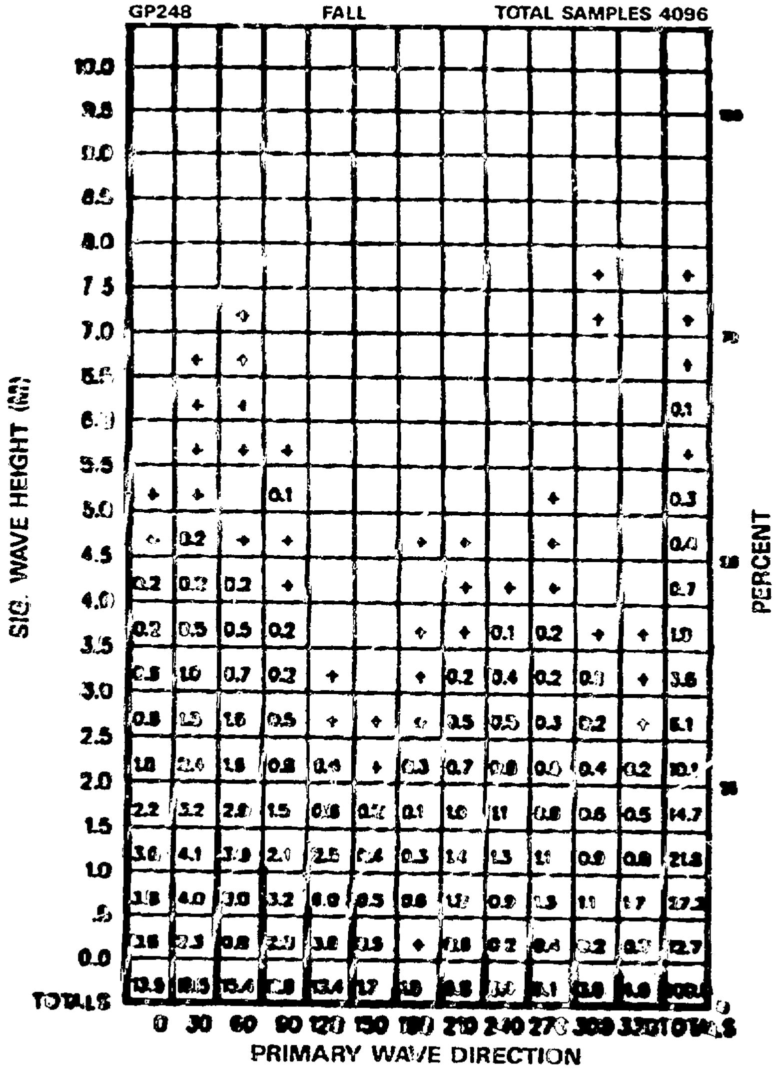


Figure A-248-5-2 Significant Wave Height vs. Primary Wave Direction

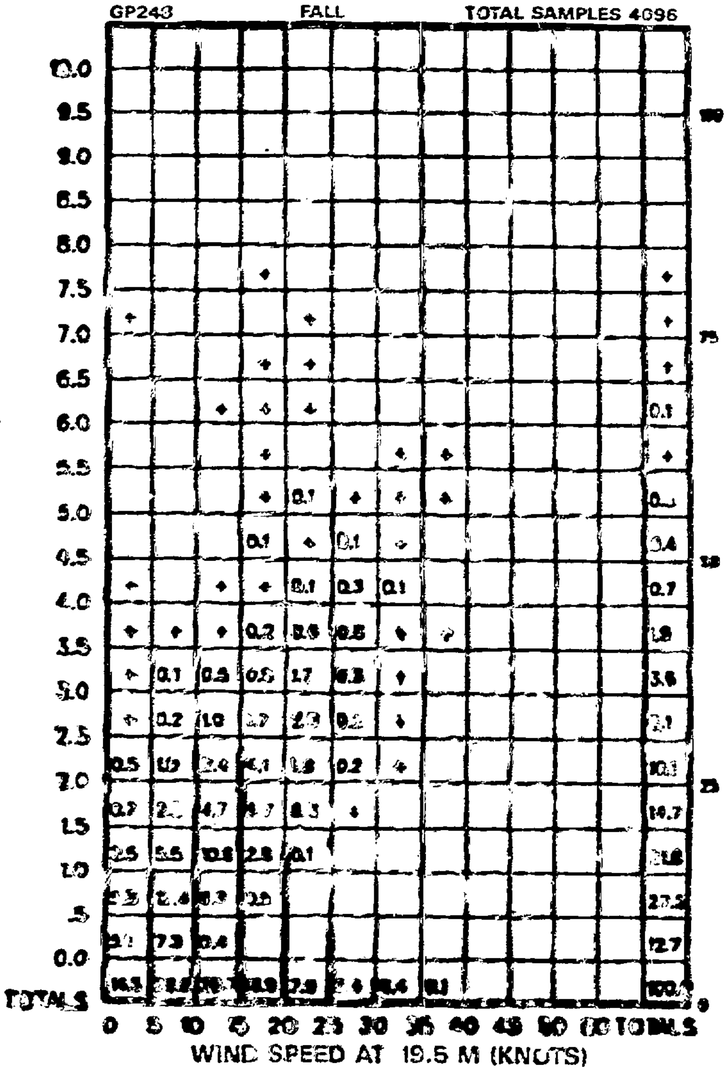


Figure A-248-5-3 Significant Wave Height vs. Wind Speed

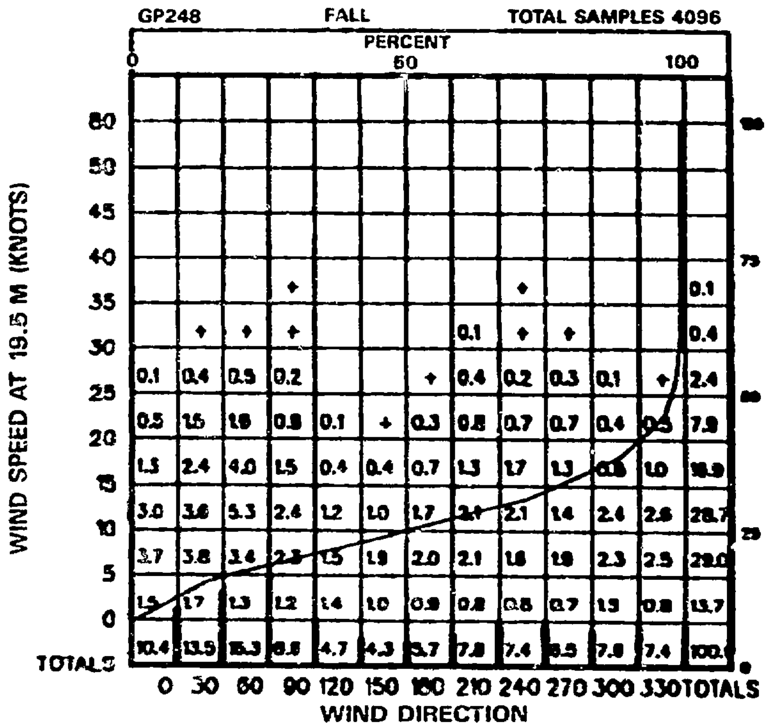


Figure A-248-5-4 Wind Speed vs. Wind Direction

APPENDIX B

NEARSHORE WAVE CLIMATOLOGY

K1 ANNUAL TOTAL SAMPLES 46612

PERCENT: 0 25 50 75 100

SIG. WAVE HEIGHT (M)	3.2	4.8	6.3	7.9	8.6	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0+																
4.5–5.0																
4.0–4.5																
3.5–4.0									•				•			•
3.0–3.5								•	•	•		•	•			•
2.5–3.0							•	•	•	•	•		•			0.1
2.0–2.5						•	•	•	•	•	•	•	•			0.3
1.5–2.0					•	0.3	0.3	0.2	•	•	•	•	•			1.0
1.0–1.5			•	0.5	1.1	1.1	0.7	0.5	0.3	0.3	•	•				4.7
.5–1.0		0.1	2.3	4.6	5.2	4.2	2.6	1.8	1.0	0.9	0.5	0.1	•			23.4
0.0–.5	0.5	0.4	8.7	11.4	7.1	8.5	4.2	3.4	1.8	2.4	0.9	•	•			49.1
•	0.8	1.7	5.4	4.3	3.1	2.6	1.1	0.8	0.4	0.8	0.3	•	•		•	21.3
TOTALS	1.3	2.2	16.4	20.7	16.6	16.8	9.0	7.1	3.4	4.3	1.8	0.3	•		•	100.0

MODAL WAVE PERIOD (SEC)

• Percentage of Observations from Directions 195 to 345

Figure B-K1-1-1 Significant Wave Height vs. Modal Wave Period

K1 ANNUAL TOTAL SAMPLES 46612

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	•	TOTALS
4.5+									
4.0–4.5									
3.5–4.0									
3.0–3.5			+						
2.5–3.0			0.1	0.2					0.3
2.0–2.5		0.1	0.2	0.8	0.1				1.2
1.5–2.0	+	0.6	0.5	3.0	0.3	0.1	0.2		4.7
1.0–1.5	0.1	3.0	2.1	11.3	5.8	0.6	0.7		23.6
0.5–1.0	0.2	5.0	2.7	26.5	16.5	3.2	0.9		49.0
•								21.2	
TOTALS	0.3	8.7	5.6	35.8	22.7	3.9	1.8		100.0

PRIMARY WAVE DIRECTION

• Percentage of Observations From Directions 195° to 345°

Figure B-K1-1-2 Significant Wave Height vs. Primary Wave Direction

K1 WINTER TOTAL SAMPLES 12696

PERCENT: 0, 25, 50, 75, 100

SIG. WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0–4.5																
4.5–4.0																
4.0–3.5									•				•			•
3.5–3.0								•	•			•	•			•
3.0–2.5							•	•			•		•			0.2
2.5–2.0						•	•	0.2	•		0.1	•	•			0.5
2.0–1.5					•	0.4	0.3	0.3	0.1	•	•	•	•			1.4
1.5–1.0			•	0.5	1.5	1.3	1.1	1.2	0.6	0.5	0.1	•				6.8
1.0–.5		0.1	1.8	3.7	5.1	4.8	3.4	3.3	1.6	1.1	0.8	0.3	•			26.2
.5–0.0	0.3	0.3	4.1	5.7	6.5	5.9	4.3	3.6	1.4	1.2	1.3	0.2	•			35.0
•	0.4	1.5	6.8	6.4	5.1	4.3	1.8	1.3	0.8	1.2	0.8	•	•		•	30.0
TOTALS	0.7	1.9	12.6	16.3	18.1	16.6	11.3	9.9	4.3	4.1	3.1	0.6	0.1		•	100.0

MODAL WAVE PERIOD (SEC)

• Percentage of Observations from Directions 195 to 345

Figure B-K1-2-1 Significant Wave Height vs. Modal Wave Period

K1 WINTER TOTAL SAMPLES 12696

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	•	TOTALS
4.5+–4.0									
4.0–3.5									
3.5–3.0				0.1					0.1
3.0–2.5			+	0.1					0.1
2.5–2.0		+	0.1	0.4					0.5
2.0–1.5	+	0.1	0.3	0.9	0.1		0.1		1.5
1.5–1.0	+	0.3	1.3	4.0	0.6	0.2	0.2		6.6
1.0–0.5	0.1	1.5	4.3	12.7	5.9	0.8	1.1		26.4
0.5–0	0.2	2.0	5.2	16.5	9.0	1.2	1.1		35.2
•								29.6	
TOTALS	0.3	3.9	11.2	34.7	15.6	2.2	2.5		100.0

PRIMARY WAVE DIRECTION

• Percentage of Observations From Directions 195° to 345°

Figure B-K1-2-2 Significant Wave Height vs. Primary Wave Direction

K1 SPRING TOTAL SAMPLES 12130

PERCENT: 0 25 50 75 100

SIG. WAVE HEIGHT (M)	3.2	4.3	5.3	7.5	8.6	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0																
4.5																
4.0																
3.5																
3.0																
2.5								*								*
2.0						*		*	*	*						0.2
1.5					*	0.7	0.1	0.2	0.1	*						0.6
1.0			*	0.4	1.1	0.7	0.3	0.5	0.1	*	*					3.0
.5		*	7.0	5.4	6.1	4.0	2.4	1.6	0.5	0.7	0.4					23.1
0.0	0.5	0.3	2.4	13.7	7.5	10.4	4.4	5.1	2.3	2.1	0.7					52.1
*	1.0	2.3	3.3	4.1	2.8	2.6	5.5	1.0	0.6	0.5	0.1					21.0
TOTALS	1.5	2.8	16.3	23.8	17.6	18.0	8.5	8.1	3.1	3.4	1.2					100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations from Directions 195 to 345

Figure B-K1-3-1 Significant Wave Height vs. Modal Wave Period

K1 SPRING TOTAL SAMPLES 12130

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5									
3.0									
2.5									
2.0				0.1					0.1
1.5		+	0.1	0.5					0.6
1.0	+	0.1	0.1	2.1	0.5	0.1	0.1		3.0
0.5	+	0.5	1.2	10.9	9.1	0.8	0.8		23.3
0	0.1	1.3	2.3	20.1	22.0	5.3	1.0		52.1
*								20.9	
TOTALS	0.1	1.9	3.7	33.7	31.6	6.2	1.9		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure B-K1-3-2 Significant Wave Height vs. Primary Wave Direction

K1 SUMMER TOTAL SAMPLES 9726

PERCENT: 0 25 50 75 100

SIG. WAVE HEIGHT (M)	3.2	4.3	6.3	7.5	8.6	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0																
4.5																
4.0																
3.5																
3.0																
2.5							*	*	*							*
2.0						*	*	*								0.1
1.5					*	0.1	*	*								0.3
1.0				0.2	0.2	0.3	0.2	0.1	*	*						1.0
.5		*	1.4	2.6	3.4	3.1	1.6	0.7	0.3	0.2	*					14.0
0.0	0.3	0.1	17.1	20.2	10.3	11.8	4.4	3.4	1.0	1.6	0.3					71.0
*	1.6	1.5	4.2	2.5	1.9	1.4	0.6	0.5	0.3	0.2	*					13.6
TOTALS	3.5	1.6	22.7	20.3	16.1	16.8	6.7	4.8	3.4	2.3	0.4					100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations from Directions 195 to 345

Figure B-K1-4-1 Significant Wave Height vs. Modal Wave Period

K1 SUMMER TOTAL SAMPLES 9726

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5									
3.0									
2.5				+					+
2.0				+					+
1.5			+	0.2					0.2
1.0		+	0.1	0.6	0.2	0.1			1.0
0.5	+	0.1	0.3	5.6	[illegible]	[illegible]	0.2		14.1
0	0.1	0.9	0.8	24.6	36.8	6.9	0.9		71.0
*								13.7	
TOTALS	0.1	1.0	1.2	31.0	44.4	7.5	1.1		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure B-K1-4-2 Significant Wave Height vs. Primary Wave Direction

K1 FALL TOTAL SAMPLES 12060

PERCENT: 0, 25, 50, 75, 100

SIG. WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.8	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0																
4.5																
4.0																
3.5																
3.0								*								*
2.5							*	*	*	*						0.2
2.0							*	*	*	0.1	*					0.4
1.5				*	0.1	0.3	0.4	0.3	*	*	*					1.3
1.0			0.1	0.7	1.6	2.1	1.2	0.7	0.3	0.5	0.1	*				7.3
.5		0.3	3.5	6.3	5.1	4.8	2.9	1.8	1.5	1.5	0.6	*				28.6
0.0	0.7	0.7	8.2	8.0	6.9	4.3	3.8	3.6	1.8	2.4	1.2	*	*			43.7
*	0.3	1.7	3.3	2.7	2.0	2.8	0.7	0.5	0.3	0.3	0.2	*			*	18.5
TOTALS	1.4	2.8	17.1	18.8	16.5	13.6	9.2	6.9	4.1	3.8	2.3	0.2	*		*	100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations from Directions 195 to 345

Figure B-K2-5-1 Significant Wave Height vs. Modal Wave Period

K1 FALL TOTAL SAMPLES 12060

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5									
3.0				0.1					0.1
2.5			0.1	0.1					0.2
2.0		+	0.1	0.2					0.3
1.5		0.1	0.3	0.7	0.1				1.2
1.0	+	0.4	1.5	5.3	0.2	0.1	0.1		7.6
0.5	0.1	1.8	4.9	17.1	3.5	0.6	0.5		28.5
0	0.2	3.0	6.0	23.6	8.6	1.1	0.8		43.3
*								18.8	
TOTALS	0.3	5.3	12.9	47.1	12.4	1.8	1.4		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure B-K1-5-2 Significant Wave Height vs. Primary Wave Direction

K2 ANNUAL TOTAL SAMPLES 46612

PERCENT

0 25 50 75 100

SIG. WAVE HEIGHT (M)	3.2	4.6	6.3	7.5	8.6	9.7	10.9	12.4	13.6	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0																
4.5																
4.0																
3.5								*								*
3.0								*	*			*	*			*
2.5					*		*	*	*	*	*					*
2.0					*	*	*	*	*	*	*	*	*			0.3
1.5				*	0.1	0.3	0.2	0.2	*	*	*	*	*			1.0
1.0			0.1	0.5	1.0	1.1	0.8	0.6	0.3	0.3	*	*				4.9
.5		0.2	2.4	5.1	5.7	4.7	7.3	1.8	1.0	1.0	0.5	0.1	*			25.2
0.0	0.5	0.3	6.5	10.8	8.7	4.0	4.4	3.3	1.6	2.4	0.8	*	*			47.2
*	0.8	1.7	3.4	4.3	2.1	2.8	1.1	0.8	0.4	0.6	0.1	*	*		*	21.3
TOTALS	1.3	2.2	16.4	20.7	16.4	16.8	8.8	7.1	2.4	4.3	1.6	0.3	*		*	100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations from Directions 195 to 345

Figure B-K2-1-1 Significant Wave Height vs. Modal Wave Period

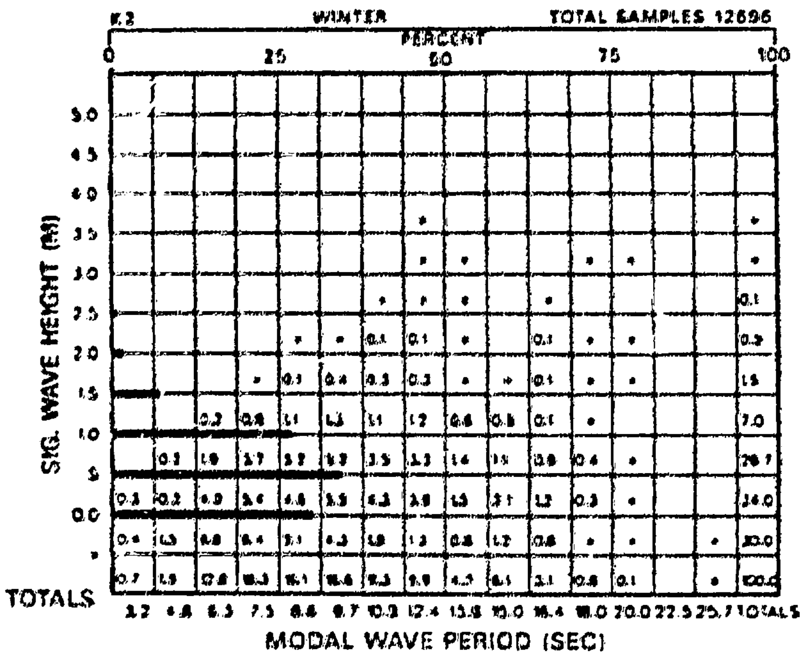
K2 ANNUAL TOTAL SAMPLES 46612

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5									
3.0									
2.5			+	0.1					0.1
2.0			0.1	0.1					0.2
1.5		+	0.3	0.5	0.1	+	0.1		1.0
1.0	+	0.2	1.3	2.4	0.7	0.2	0.3		5.1
0.5	0.1	0.9	5.2	10.1	7.3	0.6	0.6		24.8
0	0.7	1.8	8.0	19.1	16.4	2.4	0.7		48.5
*								20.3	
TOTALS	0.2	2.9	14.9	32.3	24.5	3.2	1.7		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure B-K2-1-2 Significant Wave Height vs. Primary Wave Direction



* Percentage of Observations from Directions 195 to 345

Figure B-K2-2-1 Significant Wave Height vs. Modal Wave Period

K2 WINTER TOTAL SAMPLES 12696

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5									
3.0		+	0.1						0.1
2.5			0.1	0.1					0.2
2.0		+	0.3	0.1			0.1		0.5
1.5	+	0.1	0.6	0.4	0.2	0.1	0.2		1.6
1.0	+	0.2	2.9	2.4	0.8	0.1	0.6		7.0
0.5	0.1	1.3	11.0	7.6	5.8	0.2	0.8		26.8
0	0.1	1.8	14.4	10.1	6.8	0.4	0.8		34.4
*								29.4	
TOTALS	0.2	3.4	29.4	20.7	13.6	0.8	2.5		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Direction: 195° to 345°

Figure B-K2-2-2 Significant Wave Height vs. Primary Wave Direction

K2 SPRING TOTAL SAMPLES 12130

PERCENT: 0 25 50 75 100

SIG. WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0																
4.5																
4.0																
3.5																
3.0																
2.5					+											+
2.0						+		+	+	+						0.1
1.5				+	0.1	0.2	+	0.2	0.2	+						0.8
1.0			0.1	0.5	1.0	0.7	0.4	0.3	+	+	+					3.2
.5		0.2	7.3	8.3	7.1	4.8	2.6	1.9	0.9	0.7	0.3					28.4
0.0	0.5	0.2	7.1	12.6	8.5	9.7	4.1	2.8	2.0	2.0	0.7					48.8
*	1.0	2.2	3.3	4.1	2.8	2.8	0.9	1.0	0.4	0.5	0.1					21.0
TOTALS	1.5	7.6	14.7	23.5	17.8	18.0	9.1	6.1	3.1	3.4	1.2					100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations from Directions 195 to 345

Figure B-K2-3-1 Significant Wave Height vs. Modal Wave Period

K2 SPRING TOTAL SAMPLES 12130

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5									
3.0									
2.5				+					+
2.0			0.1						0.1
1.5		+	0.2	0.2	0.1	0.1	0.2		0.8
1.0		0.1	0.3	1.6	0.6	0.2	0.3		3.1
0.5	+	0.4	3.7	10.0	10.3	1.2	0.7		26.3
0	0.1	1.3	8.0	16.9	19.0	3.6	0.6		48.5
*								21.2	
TOTALS	0.1	1.8	12.3	28.7	29.0	5.1	1.8		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure B-K2-3-2 Significant Wave Height vs. Primary Wave Direction

K2 SUMMER TOTAL SAMPLES 9726

PERCENT: 0 25 50 75 100

SIG. WAVE HEIGHT (M)	3.7	4.8	6.3	7.5	8.8	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0																
4.5																
4.0																
3.5																
3.0																
2.5							+		+							+
2.0						+	+	+								0.1
1.5				+	+	0.2	+	+								0.4
1.0			0.1	0.2	0.2	0.3	0.2	0.2	+	+						1.3
.5		+	1.8	2.5	3.1	3.9	1.7	0.8	0.3	0.3	+					17.8
0.0	0.5	0.1	[illegible]	10.1	8.5	11.0	4.0	3.3	0.9	1.7	0.4					67.1
*	1.4	1.5	4.2	2.3	1.3	1.4	0.5	0.5	0.2	0.2	+					13.8
TOTALS	1.8	1.6	22.1	23.3	16.1	18.8	6.7	4.8	1.4	2.3	0.4					100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations from Directions 195 to 345

Figure B-K2-4-1 Significant Wave Height vs. Modal Wave Period

K2 SUMMER TOTAL SAMPLES 9726

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5									
3.0									
2.5				+					+
2.0				+					+
1.5			0.1	0.1	0.1	0.1			0.4
1.0		+	0.2	0.7	0.7	0.2	0.1		1.9
0.5	+	0.1	0.7	6.2	9.2	1.0	0.3		17.5
0	0.1	0.9	2.2	24.7	33.3	5.2	0.7		67.1
*								13.1	
TOTALS	0.1	1.0	3.2	31.7	43.3	6.5	1.1		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure B-K2-4-2 Significant Wave Height vs. Primary Wave Direction

SIG. WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0																
4.5																
4.0																
3.5																
3.0								*	*	*						*
2.5							*	*	*	*						0.2
2.0						*	*	0.1	*	*	*					0.3
1.5					*	0.3	0.3	0.3	*	0.1	*					1.6
1.0			*	0.7	1.8	2.1	1.3	0.7	0.3	0.5	0.1	*				7.5
.5		0.2	3.8	6.5	5.0	4.5	7.8	1.8	1.6	1.5	0.8	*				28.4
0.0	0.7	0.8	7.9	7.9	8.8	6.3	3.8	2.4	1.7	2.4	1.2	*	*			43.3
*	0.7	1.7	3.3	3.7	3.0	2.0	0.7	0.3	0.3	0.3	0.2	*			*	18.5
TOTALS	1.4	2.8	17.1	18.9	18.6	15.6	13.2	6.9	4.1	5.0	2.3	0.2	*		*	100.0

K2 FALL TOTAL SAMPLES 12060

PERCENT 0 25 50 75 100

MODAL WAVE PERIOD (SEC)

* Percentage of Observations from Directions 195 to 345

Figure B-K1-5-1 Significant Wave Height vs. Modal Wave Period

K2 FALL TOTAL SAMPLES 12060

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5									
3.0									
2.5			+	0.2					0.2
2.0			0.1	0.2					0.3
1.5		+	0.2	1.1	0.1		0.1		1.5
1.0	+	0.4	1.8	4.7	0.5	0.1	0.2		7.5
0.5	0.1	1.8	5.5	16.7	3.8	0.2	0.5		28.6
0	0.2	3.2	7.2	24.7	7.5	0.3	0.6		43.7
*								18.2	
TOTALS	0.3	5.4	14.6	47.6	11.9	0.6	1.4		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure B-K2-5-2 Significant Wave Height vs. Primary Wave Direction

C1 ANNUAL TOTAL SAMPLES 46612

PERCENT: 0 25 50 75 100

SIG. WAVE HEIGHT (M)	3.2	4.8	6.3	7.3	8.6	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0											*	*	*			*
4.5								*	*	*	*	*	*			*
4.0								*	*	*	*	*	*			*
3.5							*	*	*	*	*	*	*			0.2
3.0						*	*	*	*	*	*	*	*			0.3
2.5						0.2	0.2	0.1	*	*	*		*			0.6
2.0					0.2	0.6	0.3	0.3	0.1	0.1	*	*				1.6
1.5			*	0.4	1.1	0.8	0.6	0.8	0.2	0.1	*	*				4.0
1.0			3.8	2.2	1.9	1.2	1.3	1.0	0.8	0.4	0.2	*				10.2
.5		0.4	3.4	5.5	5.6	4.6	2.8	1.8	0.9	1.4	0.5	*	*			27.1
0.0	3.3	0.1	6.9	8.5	4.8	6.2	2.7	2.2	1.0	1.5	0.8	*	*			34.7
*	3.8	1.7	5.4	4.3	3.1	2.6	1.1	0.9	0.4	0.8	0.3	*	*		*	21.3
TOTALS	1.3	2.2	15.4	20.7	16.6	16.8	9.0	7.1	3.6	4.3	1.8	0.3	*		*	100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations from Directions 195 to 345

Figure B-C1-1-1 Significant Wave Height vs. Modal Wave Period

C1 ANNUAL TOTAL SAMPLES 46612

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+			+						+
4.0			+						+
3.5		+	0.1	0.1					0.2
3.0		+	0.2	0.1					0.3
2.5		+	0.3	0.2					0.5
2.0		0.1	0.9	0.6					1.6
1.5	+	0.2	2.1	1.4	0.2	0.1	0.2		4.2
1.0	+	0.4	4.6	3.0	1.3	0.4	0.5		10.2
0.5	0.1	1.1	7.2	5.3	10.2	2.7	0.8		27.4
0	0.1	0.7	5.9	6.3	13.9	6.6	1.1		34.6
*								21.1	
TOTALS	0.2	2.5	21.3	16.9	25.6	9.8	2.6		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure B-C1-1-2 Significant Wave Height vs. Primary Wave Direction

C1 WINTER TOTAL SAMPLES 12696

PERCENT 0 25 50 75 100

SIG. WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0											*	*	*			*
4.5								*	*		*	*	*			*
4.0								*	*		*	*	*			0.1
3.5							*	0.1	*		*	*	*			0.3
3.0							*	0.2	*		*	*	*			0.4
2.5						0.2	0.4	0.2	0.1	*	*		*			1.0
2.0					0.3	0.7	0.4	0.6	0.3	0.2	*	*				2.4
1.5				0.5	1.1	0.9	0.8	1.2	0.3	0.3	0.2	*				5.6
1.0			0.6	1.8	2.2	2.4	1.9	1.8	1.0	0.5	0.6	0.2				13.1
.5		0.4	2.5	4.0	4.8	4.8	3.3	2.6	0.8	1.0	0.8	0.2	*			26.3
0.0	0.3	0.1	2.7	3.6	2.6	3.4	2.4	2.1	0.9	1.0	0.7	0.1	*			20.7
*	2.4	1.5	8.8	6.4	5.1	4.3	1.9	1.3	0.8	1.2	0.6	*	*		*	30.0
TOTALS	2.7	1.9	12.8	16.3	15.1	16.8	10.3	9.9	4.3	6.1	3.1	0.8	0.1		*	100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations from Directions 195 to 345

Figure B-C1-2-1 Significant Wave Height vs. Modal Wave Period

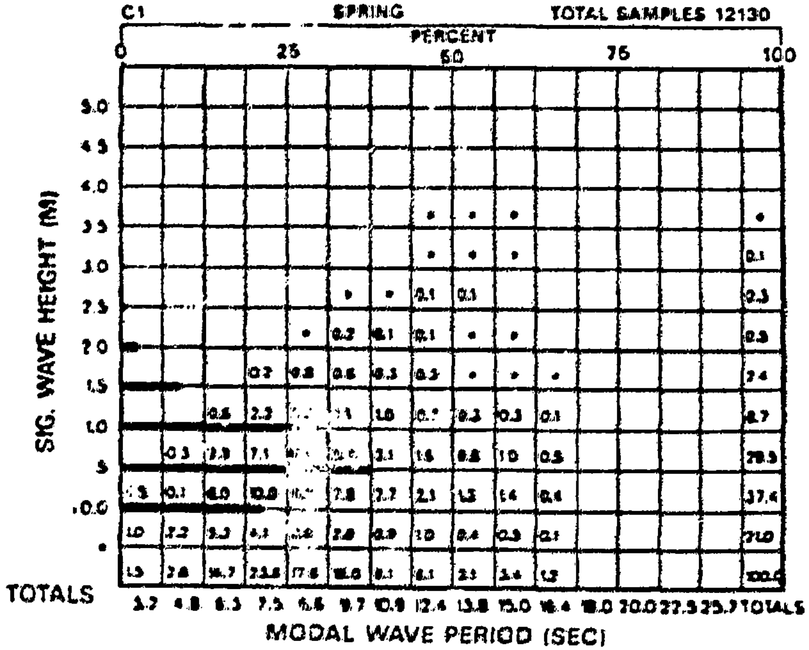
C1 WINTER TOTAL SAMPLES 12696

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+		+	0.1						0.1
4.0		+	+						+
3.5		+	0.2	0.1					0.3
3.0		0.1	0.2	0.1					0.4
2.5		0.1	0.6	0.2			0.1		1.0
2.0	+	0.1	1.7	0.4	0.1		0.1		2.4
1.5	+	0.3	3.6	1.1	0.2	0.1	0.3		5.6
1.0	0.1	0.7	7.4	1.6	1.5	0.6	0.4		12.3
0.5	0.3	1.2	11.6	3.0	6.1	2.3	1.8		26.3
0	0.2	0.8	7.9	2.9	4.9	2.4	1.6		20.7
*								30.9	
TOTALS	0.6	3.3	33.3	9.4	12.8	5.4	4.3		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure B-C1-2-2 Significant Wave Height vs.
Primary Wave Direction



* Percentage of Observations from Directions 195 to 345

Figure B-C1-3-1 Significant Wave Height vs. Modal Wave Period

C1 SPRING TOTAL SAMPLES 12130

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5			+	0.1					0.1
3.0		+	+	0.2					0.2
2.5		+	0.1	0.2					0.3
2.0		+	0.1	0.3					0.4
1.5		0.1	0.3	1.7	0.2	0.1	0.1		2.5
1.0		0.3	1.1	5.1	1.4	0.7	0.7		9.3
0.5		0.8	1.6	7.9	12.6	5.5	1.3		29.7
0	0.1	0.7	1.5	8.3	13.5	10.7	1.7		36.5
*								21.0	
TOTALS	0.1	1.9	4.7	23.8	27.7	17.0	3.8		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure B-C1-3-2 Significant Wave Height vs. Primary Wave Direction

SIG. WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0																
4.5																
4.0							*		*							*
3.5						*	*	*								*
3.0						0.1	*	*								0.2
2.5					*	0.2	*	*	*							0.3
2.0				*	0.2	0.3	*	*		*						0.6
1.5			0.3	0.7	0.6	0.8	0.3	0.2	0.1		*					2.9
1.0		0.1	7.9	3.9	6.5	4.8	2.1	1.1	0.3	0.6	*					24.3
.5	0.5	*	0.4	16.2	7.6	9.5	2.4	2.5	0.8	1.6	0.3					57.9
0.0	1.4	1.5	4.7	2.5	1.7	1.4	0.5	0.3	0.3	0.2	*					13.8
TOTALS	1.8	1.6	22.7	25.3	16.1	9.6	6.7	4.8	1.6	2.1	0.4					100.0

C1 SUMMER TOTAL SAMPLES 9726

PERCENT: 0, 25, 50, 75, 100

MODAL WAVE PERIOD (SEC)

* Percentage of Observations from Directions 195 to 345

Figure B-C1-4-1 Significant Wave Height vs. Modal Wave Period

C1 SUMMER TOTAL SAMPLES 9726

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5				0.1					0.1
3.0			+	0.2					0.2
2.5		+	0.2	0.1					0.3
2.0		+	0.2	0.3	0.2				0.7
1.5	+	0.2	0.5	1.0	0.9	0.2	0.2		3.0
1.0	1.0	0.3	1.4	2.8	15.1	3.4	1.4		24.5
0.5	0.5	0.4	1.5	8.5	30.7	11.8	4.7		58.1
0								13.1	
TOTALS	0.6	0.9	3.8	13.0	46.9	15.4	6.3		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure B-C1-4-2 Significant Wave Height vs. Primary Wave Direction

C1 FALL TOTAL SAMPLES 12060

PERCENT: 0 25 50 75 100

SIG WAVE HEIGHT (M)	3.2	4.8	6.3	7.3	8.6	9.7	10.8	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0																
4.5									*	*						*
4.0								*	*	*						0.1
3.5							*	*	*	*	*					0.3
3.0						*	0.2	0.1	*	*	*					0.4
2.5						0.1	0.3	0.2	*	*	*					0.9
2.0					0.3	1.2	0.3	0.4	0.1	0.2	*	*				2.8
1.5			*	0.5	2.0	1.4	1.6	0.5	0.2	0.4	0.2	*				6.7
1.0			1.4	2.8	2.3	2.4	1.8	1.0	0.8	0.8	0.3	*				14.6
.5		0.7	3.2	3.1	4.7	3.5	2.6	2.8	1.4	1.7	0.5	*				27.3
0.0	0.7	0.3	5.2	5.3	4.3	4.8	2.3	2.8	1.0	1.2	0.5	*	*			28.0
*	0.1	1.7	5.3	2.7	2.0	2.8	0.7	0.5	0.3	0.3	0.2	*			*	18.5
TOTALS	1.4	2.9	17.1	18.9	18.8	15.6	8.2	6.9	4.1	3.0	2.3	0.2	*		*	100.0

MODAL WAVE PERIOD

*Percentage of Observations from Directions 195 to to 345

Figure B-C1-5-1 Significant Wave Height vs. Modal Wave Period

C1 FALL TOTAL SAMPLES 12060

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+			0.1						0.1
4.0			0.1	0.1					0.2
3.5		*	0.2	0.1					0.3
3.0		*	0.3	0.2					0.5
2.5		*	0.7	0.2					0.9
2.0		0.8	1.7	1.0					3.5
1.5			3.2	2.1	0.1		0.2		6.7
1.0	*	2.3	6.4	34.2	1.0	0.1	0.4		14.4
0.5	0.1	4.2	9.2	6.6	4.4	1.5	1.2		27.2
0	0.1	4.0	6.8	7.0	6.6	2.2	1.1		27.8
*								18.4	
TOTALS	0.2	12.4	28.7	21.5	12.1	3.8	2.9		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure B-C1-5-2 Significant Wave Height vs. Primary Wave Direction

C2 ANNUAL TOTAL SAMPLES 46812

PERCENT (0 – 25 – 50 – 75 – 100)

SIG. WAVE HEIGHT (M)	3.2	4.8	6.3	7.3	8.5	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	[illegible]	TOTALS
5.0																
4.5																
4.0																
3.5								*			*					*
3.0								*	*			*	*			*
2.5							*	*	*	*	*		*			*
2.0					*	*	*	*	*	*	*	*	*			0.1
1.5				*	0.1	0.3	0.4	0.3	*	*	*	*				1.2
1.0			0.1	0.8	1.3	1.5	0.9	0.7	0.3	0.3	*	*				5.8
.5		0.2	2.7	3.5	3.8	4.5	7.8	1.8	0.8	1.0	0.5	0.1	*			25.8
0.0	0.5	0.3	6.2	10.3	6.3	7.5	4.0	3.2	1.3	2.3	0.9	*	*			45.6
*	0.8	1.7	3.4	4.3	3.1	2.8	1.1	0.8	0.4	0.6	0.3	*	*		*	21.5
TOTALS	1.3	7.2	[illegible]	20.7	[illegible]	[illegible]	[illegible]	7.1	2.4	4.3	1.8	0.3	*		*	100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations from Directions 195 to 345

Figure B-C2-1-1 Significant Wave Height vs. Modal Wave Period

C2 ANNUAL TOTAL SAMPLES 46812

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5									
3.0			+	+					+
2.5			+	0.2					0.2
2.0		+	0.1	0.2					0.3
1.5		0.1	0.3	0.6	0.1	0.1	0.1		1.3
1.0	+	0.3	1.7	3.3	0.6	0.2	0.3		6.4
0.5	0.1	1.2	4.0	10.9	7.6	0.7	0.7		25.2
0	0.1	1.7	5.4	17.7	16.5	2.2	0.8		44.4
*								22.2	
TOTALS	0.2	3.3	11.5	32.9	24.8	3.2	1.9		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure B-C2-1-2 Significant Wave Height vs. Primary Wave Direction

TOTAL SAMPLES 12696

PERCENT

SIG. WAVE HEIGHT (M)	3.2	4.6	6.3	7.5	8.6	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0																
4.5																
4.0																
3.5								*			*					*
3.0								*	*			*	*			*
2.5							*	*	*		*		*			0.1
2.0					*	*	0.1	0.1	*		0.1	*	*			0.6
1.5				*	0.1	0.5	0.8	0.4	*	*	0.1	*				1.9
1.0			0.2	0.6	1.8	2.1	1.5	1.4	0.6	0.5	0.1	*				8.9
.5		0.7	2.3	4.4	3.4	4.7	3.1	3.2	1.8	1.3	0.8	0.3	*			27.3
0.0	0.1	0.2	3.6	4.7	3.8	3.2	4.8	2.5	1.5	2.9	1.2	0.3	*			31.0
*	0.4	1.3	8.8	6.4	2.1	4.3	1.9	1.3	0.8	1.7	0.8	*	*		*	30.0
TOTALS	0.7	1.9	12.8	18.3	18.1	15.8	12.3	9.9	4.3	6.6	3.1	0.8	0.1		*	100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations from Directions 195 to 345

Figure B-C2-2-1 Significant Wave Height vs. Modal Wave Period

C2 WINTER TOTAL SAMPLES 12696

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5									
3.0			+	+					+
2.5			+	0.1					0.1
2.0		0.1	0.1	0.3			0.1		0.6
1.5		0.1	0.5	1.1	0.1	0.1	0.2		2.1
1.0	+	0.4	2.2	4.6	0.8	0.4	0.6		9.0
0.5	0.1	1.3	5.8	13.2	5.5	0.6	0.8		27.3
0	+	1.4	6.2	15.3	6.6	0.7	0.8		31.0
*								29.9	
TOTALS	0.1	3.3	14.8	34.6	13.0	1.8	2.5		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure B-C2-2-2 Significant Wave Height vs. Primary Wave Direction

C2 SPRING TOTAL SAMPLES 12130

PERCENT: 0 25 50 75 100

SIG. WAVE HEIGHT (M)	3.2	4.9	6.5	7.5	8.6	9.7	10.8	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0																
4.5																
4.0																
3.5																
3.0																
2.5																
2.0					*	*		*	*	*						0.1
1.5				*	0.1	0.2	0.1	0.2	0.2	*						0.8
1.0			0.1	0.5	1.0	0.7	0.4	0.4	*	*	*					3.3
.5		0.2	2.5	6.5	7.1	4.8	2.8	1.5	0.5	0.7	0.3					26.9
0.0	0.3	0.2	6.8	12.6	6.6	9.5	4.2	2.8	1.9	2.8	0.3					47.8
*	1.0	2.2	3.3	4.1	7.8	7.8	0.8	1.0	0.4	0.5	0.1					21.0
TOTALS	1.5	2.8	16.7	23.6	17.6	18.9	8.1	6.1	3.1	3.4	1.2					100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations from Directions 195 to 345

Figure B-C2-3-1 Significant Wave Height vs. Modal Wave Period

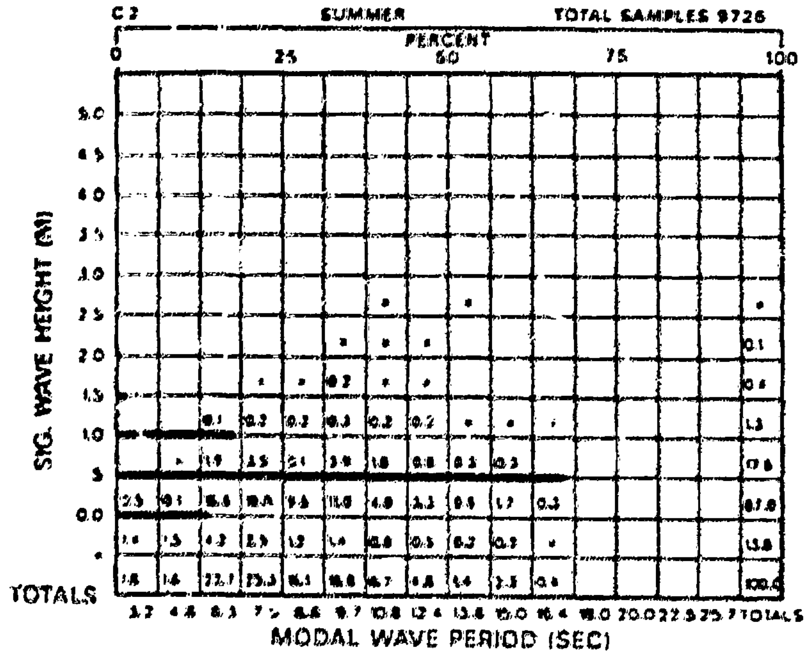
C2 SPRING TOTAL SAMPLES 12130

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5									
3.0									
2.5									
2.0			0.1	0.1	+				0.2
1.5		+	0.1	0.4	0.1	0.1	0.1		0.8
1.0		0.1	0.2	1.8	0.6	0.2	0.3		3.2
0.5	+	0.6	2.3	12.5	9.5	1.2	0.8		26.9
0	0.2	1.2	4.3	21.0	16.7	3.6	0.7		47.7
*								21.2	
TOTALS	0.2	1.9	7.0	35.8	26.9	5.1	1.9		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure B-C2-3-2 Significant Wave Height vs. Primary Wave Direction



* Percentage of Observations from Directions 195 to 345

Figure B-C2-4-1 Significant Wave Height vs. Modal Wave Period

C2 SUMMER TOTAL SAMPLES 9726

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	108°	*	TOTALS
4.5+									
4.0									
3.5									
3.0									
2.5									
2.0				0.1					0.1
1.5			0.1	0.2	0.1	*			0.4
1.0		*	0.3	0.6	0.2	0.1	*		1.2
0.5	*	0.2	0.7	7.0	8.6	0.9	0.3		17.7
0	0.1	0.8	1.8	27.0	31.1	4.8	0.7		66.9
*								13.7	
TOTALS	0.1	1.0	2.9	35.5	40.0	5.8	1.0		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure C2-4-2 Significant Wave Height vs. Primary Wave Direction

C2 FALL TOTAL SAMPLES 12060

PERCENT 0 25 50 75 100

SIG. WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.8	15.0	16.4	18.0	20.0	22.5	25.7	TOTALS
5.0																
4.5																
4.0																
3.5																
3.0								+								+
2.5							+	+	+	+						0.2
2.0							+	0.1	+	0.1	+					0.4
1.5				+	0.1	0.4	0.5	0.4	+	0.1	+					1.6
1.0			0.7	0.6	1.9	2.6	1.3	0.8	0.3	0.5	0.1	+				8.5
.5		0.3	4.0	7.2	5.6	4.5	2.8	1.8	1.5	1.6	0.6	+				29.9
0.0	0.7	0.7	7.7	7.2	8.1	8.2	3.7	3.2	1.7	2.3	1.2	+	+			40.8
•	0.7	1.7	5.3	3.7	3.0	2.0	0.7	0.5	0.3	0.3	0.2	+			+	18.5
TOTALS	1.6	2.6	17.1	18.9	18.6	15.6	12.2	6.9	4.1	5.0	2.3	0.2	+		+	100.0

MODAL WAVE PERIOD (SEC)

• Percentage of Observations from Directions 195 to 345

Figure B-C2-5-1 Significant Wave Height vs. Modal Wave Period

C2 FALL TOTAL SAMPLES 12060

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	•	TOTALS
4.5+									
4.0									
3.5									
3.0				+					+
2.5			+	0.1					0.1
2.0		+	0.1	0.2					0.3
1.5	+	0.1	0.4	0.9	0.1		0.1		1.6
1.0	+	0.3	2.6	4.9	0.4	0.1	0.2		8.5
0.5	0.1	1.1	8.4	16.1	3.5	0.2	0.5		29.9
0	0.1	2.7	8.8	21.5	6.9	0.3	0.6		40.9
•								18.7	
TOTALS	0.2	4.2	20.3	43.7	10.9	0.6	1.4		100.0

PRIMARY WAVE DIRECTION

• Percentage of Observations From Directions 195° to 345°

Figure B-C2-5-2 Significant Wave Height vs. Primary Wave Direction

APPENDIX C

MEASURED SHORT-TERM WAVE STATISTICS

K1 WINTER 83-84 WAVE GAGE

SIGNIFICANT WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.9	15.0	16.4	18.0	*	TOTALS
4.5+														
4.0 – 4.5														
3.5 – 4.0														
3.0 – 3.5														
2.5 – 3.0			0.4	0.4	0.7									1.5
2.0 – 2.5	0.7	1.7	3.9	1.1	0.4									7.8
1.5 – 2.0	1.1	2.1	3.1	1.4	0.4	0.7	0.7							9.5
1.0 – 1.5	1.1	3.9	3.1	1.1	1.1	1.1	2.8							15.3
0.5 – 1.0	2.8	1.4	2.3	1.7	5.9	5.6	9.4	1.1						30.0
0 – 0.5	1.4	1.1	1.4	0.4	4.9	4.2	8.4	1.7	0.7					24.2
*													11.7	
TOTALS	7.1	10.2	14.0	6.1	13.4	11.6	22.4	2.8	0.7					100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations From Directions 195° to 345°

Figure C-K1/GAGE-2-1 Significant Wave Height vs. Modal Wave Period

K1 WINTER 84 WAVE GAGE

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0 – 4.5									
3.5 – 4.0									
3.0 – 3.5									
2.5 – 3.0			0.7	0.7					1.4
2.0 – 2.5		1.1	1.3	0.4		0.4			3.2
1.5 – 2.0	0.4	1.7	3.1	3.1	1.7	0.4			10.4
1.0 – 1.5	1.1	1.7	1.7	5.6	4.2	0.7			15.0
0.5 – 1.0	1.7	0.4	0.7	17.1	8.0	1.7			29.6
0 – 0.5		0.4	1.1	13.2	8.4	0.7			23.8
*								16.4	
TOTALS	3.2	5.3	8.6	40.1	22.3	3.9			100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure C-K1/GAGE-2-2 Significant Wave Height vs. Primary Wave Direction

K1 SPRING 84 WAVE GAGE

SIGNIFICANT WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.9	15.0	16.4	18.0	*	TOTALS
4.5+														
4.0–4.5														
3.5–4.0														
3.0–3.5														
2.5–3.0														
2.0–2.5			0.3											0.3
1.5–2.0	0.3	0.3		0.3										0.9
1.0–1.5	0.7	1.4	2.0	8	2.0	0.3	0.7	0.3						10.2
0.5–1.0	1.3	6.8	4.7	2.7	5.1	2.0	7.8	2.4						34.8
0–0.5	8.7	1.4	4.1	4.7	9.5	2.7	13.5	5.4	0.7					50.7
*													3.1	
TOTALS	13.1	9.9	11.1	10.5	16.6	5.0	22.0	8.1	0.7					100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations From Directions 195° to 345°

Figure C-K1/GAGE-3-1 Significant Wave Height vs. Modal Wave Period

K1 SPRING 84 WAVE GAGE

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0–4.5									
3.5–4.0									
3.0–3.5									
2.5–3.0									
2.0–2.5						0.3			0.3
1.5–2.0					0.7		0.7		1.4
1.0–1.5		0.6	1.0	2.6	4.9	1.0	0.3		10.4
0.5–1.0	0.6	1.4	2.3	12.2	10.2	6.9	0.3		33.9
0–0.5	0.6		2.3	25.3	15.1	4.6	2.6		50.5
*								3.5	
TOTALS	1.2	2.0	5.6	40.1	30.9	12.8	3.9		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure C-K1/GAGE-3-2 Significant Wave Height vs. Primary Wave Direction

SIGNIFICANT WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.9	15.0	16.4	18.0	*	TOTALS
4.5+														
4.0–4.5														
3.5–4.0														
3.0–3.5														
2.5–3.0			0.4	0.4	0.4									1.2
2.0–2.5	0.4	0.4	2.4	2.1	0.4									5.7
1.5–2.0	0.4	3.5	4.2	1.7	1.7	1.4	1.0							13.9
1.0–1.5	1.0	4.5	5.6	3.1	3.1	1.4	0.7				0.4			19.8
0.5–1.0	2.1	4.2	3.5	2.1	10.1	3.5	5.6	1.0	2.4		2.4			36.9
0–0.5	2.8	1.0	1.4	1.0	8.3	1.7	1.4	0.4	2.1		0.4			20.5
*													2.0	
TOTALS	6.7	13.6	17.5	10.4	24.0	8.0	8.7	1.4	4.5		3.2			100.0

K1 FALL 84 WAVE GAGE

MODAL WAVE PERIOD (SEC)

* Percentage of Observations From Directions 195° to 345°

Figure C-K1/GAGE-5-1 Significant Wave Height vs. Modal Wave Period

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0–4.5									
3.5–4.0									
3.0–3.5									
2.5–3.0			0.3	1.0		0.3			1.6
2.0–2.5		0.3	1.7	4.0	0.3		0.3		6.7
1.5–2.0		1.0	4.0	4.0	1.7	0.3			11.0
1.0–1.5		0.3	3.7	6.4	8.1	0.7			19.2
0.5–1.0	0.7	0.7	1.0	20.8	12.8	0.3			36.3
0–0.5	0.3	0.7	2.0	4.7	7.4	5.4	0.3		20.8
*								4.5	
TOTALS	1.0	3.0	12.7	40.9	30.3	7.0	0.6		100.0

K1 FALL 84 WAVE GAGE

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure C-K1/GAGE-5-2 Significant Wave Height vs. Primary Wave Direction

C1 WINTER 85 WAVE GAGE

SIGNIFICANT WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.9	15.0	16.4	18.0	*	TOTALS
4.5+														
4.0														
3.5														
3.0							0.3							0.3
2.5					0.6		0.3							0.9
2.0			0.3	0.3	0.3	0.6	0.8							2.3
1.5		0.3	0.6	0.8	1.4	0.8	0.6							4.5
1.0	0.3	2.8	3.6	1.7	4.8	3.1	1.7	0.6	0.6					19.2
0.5	3.9	4.7	1.4	2.5	4.5	3.9	3.3	0.6						24.8
0	13.2	3.3	1.1	2.5	11.7	4.8	2.5	0.8	2.5					42.4
*													5.6	
TOTALS	17.4	11.1	7.0	7.8	23.3	13.2	9.5	2.0	3.1					100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations From Directions 195° to 345°

Figure C-C1/GAGE-2-1 Significant Wave Height vs. Modal Wave Period

C1 WINTER WAVE GAGE

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5									
3.0			0.3						0.3
2.5			0.3	0.6					0.9
2.0		0.3	1.4	0.3	0.3				2.3
1.5		0.3	2.0	1.9	0.3				4.5
1.0	0.3	0.5	5.4	11.2	1.4	0.4			19.2
0.5	0.6	1.9	8.8	8.2	4.2	0.8	0.3		24.8
0	3.7	4.0	6.4	18.8	4.2	3.9	1.4		42.4
*								5.6	
TOTALS	4.5	7.0	24.7	41.0	10.4	5.1	1.7		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure C-C1/GAGE-2-2 Significant Wave Height vs. Primary Wave Direction

C1 — FALL 85 — WAVE GAGE

SIGNIFICANT WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.9	15.0	16.4	18.0	*	TOTALS
4.5+														
4.0														
3.5														
3.0						0.3								0.3
2.5					1.0	0.3	0.3							1.6
2.0			0.7	0.3	1.3	2.4	0.3		0.3		0.3			5.6
1.5		0.3	0.3	0.3	2.0	1.7	1.0	0.3						5.9
1.0	0.3	2.7	1.0	1.0	5.3	2.7	1.7	0.7	0.7					16.1
0.5	4.3	6.3	3.7	9.0	9.3	2.7	4.3	0.7	0.3		0.3			40.9
0	2.7	1.7	0.3	7.0	4.7	2.0	5.7	3.0	1.0					28.1
*													1.5	
TOTALS	7.3	11.0	6.0	17.6	23.6	12.1	13.3	4.7	2.3		0.6			100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations From Directions 195° to 345°

Figure C-C1/GAGE-5-1 Significant Wave Height vs. Modal Wave Period

C1 — FALL 85 — WAVE GAGE

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5									
3.0		0.3							0.3
2.5			1.3	0.3					1.6
2.0			4.7	1.3	0.3				6.3
1.5			3.7	1.0	0.3	0.3			5.3
1.0		0.3	11.7	1.3	1.0	1.3	0.3		15.9
0.5	1.0		16.7	20.7	0.3	1.3	0.3		40.3
0	0.7	0.3	12.4	11.4	1.3	2.0	0.3		28.4
*								1.9	
TOTALS	1.7	0.9	50.5	36.0	3.2	4.9	0.9		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure C-C1/GAGE-5-2 Significant Wave Height vs. Primary Wave Direction

APPENDIX D

TRANSFORMED SHORT-TERM WAVE STATISTICS

K1 FALL 84 SOWM

SIGNIFICANT WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.[illegible]	9.7	10.9	12.4	13.9	15.0	16.4	18.0	*	TOTALS
4.5+														
4.0–4.5														
3.5–4.0														
3.0–3.5														
2.5–3.0							0.6	2.2						2.8
2.0–2.5						1.1	1.1	5.6						7.8
1.5–2.0					5.0	2.8	2.6	5.0	0.6					16.2
1.0–1.5			3.4	11.7	3.9	3.4	3.9	2.2	0.6					29.1
0.5–1.0		0.6	2.8	6.2	3.9	2.2	1.7	1.7						19.1
0–0.5	0.6	1.7	7.8	3.4	1.1	1.1	2.2	0.8	0.6					19.1
*													5.9	
TOTALS	0.6	2.3	14.0	21.3	13.9	10.6	12.3	17.3	1.8					100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations From Directions 195° to 345°

Figure D-K1/SOWM-5-1 Significant Wave Height vs. Modal Wave Period

K1 FALL 84 SOWM

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0–4.5									
3.5–4.0									
3.0–3.5									
2.5–3.0			1.7	1.1					2.8
2.0–2.5			2.3	5.6		0.6			8.5
1.5–2.0			5.1	9.6	1.1	0.6			16.4
1.0–1.5	1.1		3.4	17.4	7.4	0.6			29.9
0.5–1.0	1.1	1.6	1.7	9.0	4.5	1.1	0.6		19.6
0–0.5	0.6	1.1	2.3	6.8	1.7	1.7	2.8		17.0
*								E.8	
TOTALS	2.8	2.7	16.5	49.5	14.7	4.6	3.4		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure D-K1/SOWM-5-2 Significant Wave Height vs. Primary Wave Direction

K1 — WINTER 84 — SOWM

SIGNIFICANT WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.8	12.4	13.9	15.0	16.4	18.0	*	TOTALS
4.5+														
4.0														
3.5														
3.0														
2.5								0.6						0.6
2.0				0.6		0.6	1.2	5.7						8.1
1.5				0.6	1.7	2.3	3.5	6.3						14.4
1.0			2.9	2.9	6.2	2.3	3.5	2.9	0.6					20.3
0.5		0.6	8.6	5.7	5.7	2.9	3.5	2.3						29.3
0	0.6	1.7		0.6	0.6	0.6								4.1
*													23.2	
TOTALS	0.6	2.3	11.5	10.4	13.2	8.7	11.7	17.8	0.6					100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations From Directions 195° to 345°

Figure D-K1/SOWM-2-1 Significant Wave Height vs. Modal Wave Period

K1 — WINTER 84 — SOWM

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0									
3.5									
3.0									
2.5				0.6					0.6
2.0	0.6		1.7	4.0	1.1	0.6			8.0
1.5		0.6	1.7	8.6	1.1	1.1			13.1
1.0	1.2	0.6	3.5	7.8	4.6		2.3		20.0
0.5			1.7	13.8	6.3	2.9	4.0		28.7
0				0.6	1.2	2.3	0.6		4.7
*								24.9	
TOTALS	1.8	1.2	8.6	35.4	14.3	6.9	6.9		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure D-K1/SOWM-2-2 Significant Wave Height vs. Primary Wave Direction

C1 — WINTER 85 — SOWM

SIGNIFICANT WAVE HEIGHT (M)	3.2	4.8	6.3	7.5	8.6	9.7	10.9	12.4	13.9	15.0	16.4	18.0	*	TOTALS
4.5+														
4.0 – 4.5+							0.7							0.7
3.5 – 4.0							0.7	1.7						3.4
3.0 – 3.5						0.7	1.3	2.7						4.7
2.5 – 3.0					2.7	1.3	0.7	1.3						6.0
2.0 – 2.5			2.0	4.7	1.3	2.0	2.0	3.3						15.3
1.5 – 2.0			0.7	2.6	2.7	2.7	0.6	3.3						12.6
1.0 – 1.5		1.3	1.3	2.0		2.0	2.0	1.3	1.3	0.7	0.7			12.6
0.5 – 1.0		1.3	4.0	2.7	2.0	3.3		0.7		0.6				14.6
0 – 0.5	0.7	4.1	6.7	2.0	2.0	0.7	0.7							16.9
*													13.2	
TOTALS	0.7	6.7	14.7	14.0	10.7	12.7	8.7	15.3	1.3	1.3	0.7			100.0

MODAL WAVE PERIOD (SEC)

* Percentage of Observations From Directions 195° to 345°

Figure D-C1/SOWM-2-1 Significant Wave Height vs. Modal Wave Period

C1 — WINTER — SOWM

SIGNIFICANT WAVE HEIGHT (M)	0°	30°	60°	90°	120°	150°	180°	*	TOTALS
4.5+									
4.0 – 4.5+				0.7					0.7
3.5 – 4.0				2.7			0.7		3.4
3.0 – 3.5			2.0	2.0	0.7				4.7
2.5 – 3.0			1.2	4.0	0.4		0.4		6.0
2.0 – 2.5			4.0	8.7	0.7		1.9		15.3
1.5 – 2.0			3.8	5.0	2.8		1.0		12.6
1.0 – 1.5			3.2	5.0	3.2	1.3			12.6
0.5 – 1.0		0.8	3.6	3.7	2.2	2.7	1.4		14.6
0 – 0.5		1.3	2.0	1.5	2.0	2.7	7.4		16.9
*								13.2	
TOTALS		2.1	19.8	33.3	12.0	6.7	12.8		100.0

PRIMARY WAVE DIRECTION

* Percentage of Observations From Directions 195° to 345°

Figure D-C1/SOWM-2-2 Significant Wave Height vs. Primary Wave Direction

APPENDIX E

DATA FORMAT DESCRIPTION

APPENDIX E
DATA FORMAT DESCRIPTION

Appendix B contains some of the following natural environment data distributions for each respective geographic location:

I. Waves and Wind

1. Significant wave height versus modal wave period
2. Significant wave height versus primary wave direction
3. Significant wave height versus wind speed
4. Wind speed versus wind direction

II. Persistence

5. Persistence of wave height
6. Persistence of wind speed

Each figure in Appendices A through D is identified by a code as detailed in Figure E.

A "standard" format has been adhered to for each environmental parameter at each location. They are described in the following paragraphs and these descriptions should be referred to in interpreting the data presented in Appendices A through D. Persistence data are presented for annual season only.

I. Waves and Wind

Data sets 1 through 4 present the percentage frequency of occurrences for various combinations of atmospheric and oceanographic parameters. The number in each square is the percentage frequency of occurrences for that particular combination of parameters indicated at that intersection of the ordinate and abscissa. The right column and bottom row of each graph present the cumulative totals for each respective row and column. As an example, in Figure A - Combined - 1 - 1, the following information can be obtained: (i) 1.2 percent of the data had a combination of 4.8 second modal wave period and 1. to 1.5 meter significant wave height, (2) 2.2 percent of significant wave heights had modal wave period of 4.8 second, (3) 20.3 percent of all significant wave heights were between 1 and 1.5 meters, and (4) these events were out of a total of 52627 samples.

II. Persistence

Data sets 5 and 6 present the persistence or duration of wave height and wind speed in terms of occurrences within a range of hours (in 6 hour increments). Again, totals are given in the right column and bottom row.

SAMPLE FIGURE NUMBER A - 235 - 1 - 1

Area — Grid Point — Season — Data Set Number

Area	Grid Point	Season	Data Set Number
A - SOWM Offshore	Comb (all 3 GP) 222 235 248	1-Annual 2-Winter 3-Spring 4-Summer 5-Fall	1. Significant wave height versus modal wave period 2. Significant wave height versus primary wave direction 3. Significant wave height versus wind speed 4. Wind speed versus wind direction 5. Persistence of wind height 6. Persistence of wind speed
B - Nearshore (Transformed)	K1 K2 C1 C2		
C - Short-Term Nearshore (Measured)	C1/Gage K1/Gage		
D - Short-Term Nearshore (Transformed)	C1/SOWM K1/SOWM		

Fig. E-1. Figure number coding system.

REFERENCES

1. Bales, S.L., W.E. Cummins and E.N. Comstock, "Potential Impact of Twenty Years Hindcast Wind and Wave Climatology on Ship Design," Marine Tech., Vol. 19, No. 2 (1982).
2. Lai, R.J. and A.L. Silver, "Shallow Water Wave Model at Cape Canaveral, Florida and Kings Bay, Georgia," Report DTNSRDC/SPD-1190-01 (Jun 1986).
3. Lai, R.J. and E.W. Foley, "Field Measurements of Nearshore Wave Environment at Cape Canaveral, Florida and Kings Bay, Georgia," Report DTNSRDC/SPD-1190-02 (Jul 1986).
4. Hayes, J.G., "Ocean Current Wave Interaction Study," J. of Geophy. Res., Vol. 18 (1980).
5. Phillips, O.M., "Nonlinear Wave Dynamics," IUCEM Symposium Proceedings (1980).
6. Lai, R.J. and S.L. Bales, "Effects of the Gulf Stream on Nearshore Wave Climate," ASCE Proceedings of 20th International Conf. Coastal Engr. (1986).
7. Corson, W.D., D.T. Resio, R.M. Brooks, B.A. Ebersole, R.E. Jensen, D.S. Ragsdale, and B.A. Tracy, "Atlantic Coast Hindcast, Phase II, Wave Information," WIS Rep. 6, U.S. Army Eng. Waterway Exp. Station, Vicksburg, Mississippi (1982).
8. Lazanoff, S.M. and N. Stevenson, "An Evaluation of a Hemispheric Operational Wave Spectral Model," Tech. Note 75-3, Fleet Numberica Weather Center, Monterey, California (1975).
9. Resio, D.T. and C.L. Vincent, "A Comparison of Various Numerical Wave Prediction Techniques," OTC, Houston, Texas (1979).